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THE
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PROGRESS IN 1911

WHILE giving close attention day by day to more or less routine work, one is apt to lose his perspective even regarding the line of work with which he is most closely connected. Thus it is well for us all, occasionally, to pause and review in a broad way the work that has recently been accomplished.

In the following pages THE ELECTRIC JOURNAL presents a series of some twenty-two reviews of progress, each taking up a definite section of the engineering field with which the writer is particularly familiar, and giving in a brief and personal way the points that seem to him most worthy of mention. On looking over the list of contributors to these reviews, it will be recognized that most of the authors are men of national reputation in engineering circles and are especially well qualified to speak from their intimate, personal knowledge on the subjects given.

In presenting these reviews, no claim is made that they cover the whole field, or that each contributor presents his subject in a comprehensive and logical manner. In fact, one of the aims of this method of presentation is to get away from the formal review and to inject individuality and variety of style and treatment into a discussion which might otherwise become tiresome and monotonous owing to its sameness as compared with other similar reviews.

THE PRESENT TREND OF DEVELOPMENT IN ELECTRICAL MACHINERY

B. G. LAMME

IN looking over the field of development of electrical machinery for the past year, it appears that many of the advances are found in the direction of improvements in construction, and in operating characteristics. There has been a very decided tendency toward those designs and constructions which represent better manufacturing conditions. In the designs of the newer electrical

machinery there is evidence of a much greater refinement than heretofore; or, to express it in another way, the newer designs are the result of what might be called analytical engineering. In other words, there is much more refinement in calculation and use of materials than in the past.

This evidence of improvement along well-known lines is indicated, for example, by the more extended use of commutating poles in commutating machinery; by improved methods of ventilation in both open and enclosed machines; by the use of better materials in the machines themselves, both in the quality of material and its treatment in the course of manufacture; by the use of insulations which are adapted for temperature conditions, as well as insulation purposes, etc.

In line with these refinements, there has been a tendency toward higher speeds in rotating machinery which serves simply for conversion purposes, such as motor-generators, synchronous converters, etc. There has also been a very pronounced tendency toward higher speeds in turbo-generator work, resulting, to a great extent, from improvements and advances in mechanical construction.

There has also been a more extended use of synchronous machinery adapted for correcting power-factor, such a synchronous condensers, either operating singly or forming a member of a motor-generator or frequency changer set. This is a refinement of operation which was due to come eventually.

There has been a growing tendency toward the application of multi-speed alternating-current motors for speed adjustment in large mill work, etc., in this country; while in Europe there has been a very considerable tendency toward the use of commutator type polyphase motors operated in cascade in connection with large induction motors to obtain adjustable or variable speeds.

There have also been some advances made in the use of high-voltage direct-current for railway work, this being evidenced by the use of 1 500 volts on one large installation. In the alternating-current railway work in this country, the extension of the New Haven single-phase system has been the principal example. In Europe there has been a decided activity in the single-phase railway work in connection with trunk line service, principally at a frequency of 15 cycles.

In the smaller lines of generators and motors there has been

considerable development in getting out new lines to replace older ones, these new lines containing many refinements in design and construction based upon the general accummulated experience of past years. Radically new features are rare, except in the operating characteristics, which, in some respects, are superior to any which have been available heretofore. For example, the use of commutating poles in direct-current motors of moderate size has allowed their adaptation to service conditions which were impracticable with older types.

The growth of the electrical industry in the past has been so rapid that necessarily there was more or less crudity in the apparatus itself, due to insufficient opportunity and experience to perfect the types or designs. As long as types and applications were changing so rapidly, there was naturally insufficient opportunity for applying refinements of design and construction which were bound to come in time. These refinements, which are of leading importance in the steady growth of the business, have been taking place in the recent past, and they really represent as much advance in the electrical art as some of the apparently more radical developments which preceded them.

RECENT ADVANCES IN POWER GENERATION

EDWIN D. DREYFUS

IN power plant work some significant demonstrations have been made during the year which has just come to a close—principally in the extension of the power of single steam units, both boilers and turbines. Special developments have contributed materially toward higher plant efficiencies, and opinions generally have become crystallized as regards the field of economic application of different types of power apparatus.

Firstly, steam turbines of 20 000 kilowatts (maximum rating) have recently been installed, and it has been authentically expressed that 50 000 kilowatts in a single unit, may safely be accomplished though this may not come to pass for a few years hence. At the Delray Station of the Detroit Edison Company, individual boilers of approximately 2 400 horse-power, normal capacity, have been tested, in which was developed the fact that very liberal overloads could be maintained—three or four times the rate of evaporation regularly accepted in the past for ratings of boilers. This point to a very marked stride in the high power practicable from single

boilers, which are now almost capable of matching the demand of the present large turbine. What bears particular emphasis in such an advance as this, is the economic utilization of the materials of construction. Here we have an evident tendency toward increasing the rate of heat transference per unit area of exposed or heating surface. An analogous case exists in surface condenser work, where we find the leading exponents in this branch urging a higher rate of heat transmission through the tube surfaces, this obviously implying the proper condition of condenser design. It has, therefore, been apparent that a large reduction is being effected in the cost of providing for and generating power.

From a broad view of the steam turbine industry, we find a less divergence of the commercial designs than in former years. Especially in Great Britain and on the Continent, it is almost universally the practice to introduce the combined action and reaction elements for all large work, while impulse turbines prevail for all small powers.

The proper apportionment in power plants for efficient supply of the variable power and heating demands has been a vexing problem. An interesting solution has been evolved within the last twelve months in the construction of the automatic "bleeder" turbine which, through special control, provides efficient operation notwithstanding the fact that the maximum or minimum demand of the power and heating system, respectively, may not be co-incident.

Broader usefulness of the steam turbine has been attained through the perfecting of large reduction gears, such that they may now be used economically for direct-current generators of large capacity, centrifugal pumps, in marine service, driving of trains of coils, and similar applications, where formerly a serious compromise in efficient speeds occurred in the direct coupling of the two elements. It is deemed imperative by the engineers, who have been engaged in the development of high power machinery, that flexibility be incorporated in the large gears through floating suspension of the pinion on account of the relative magnitude of construction and also the characteristics of materials necessarily employed. Within the preceding year an important innovation of the flexible gear has been brought out, in which the pinion is supported by hydraulic pistons securing adjustment for uniform distribution of tooth pressure, the essential consideration for the success of large gears. A valuable feature incident to the hydraulic

principle is that the horse-power transmitted may be interpreted with the highest degree of accuracy from the oil pressure under the supporting pistons obtaining automatically with variable loads.

We have witnessed during the past year, a greater demand for turbines of small size for isolated power plants, exciter sets, centrifugal boiler feed pumps, driving condenser auxiliaries, centrifugal compressors for forced ventilation, cupola and smelting work etc., and this trend is undoubtedly governed by the simplicity of construction, facility of installation and ease of maintenance, owing to the uniformity of speed direction, and, therefore, the absence of reversal strains, lubrication and packing difficulties.

Opinion has been largely settled upon the most profitable application of gas power. It is manifestly, the most important in natural gas districts, and ranks second in blast furnace practice. Under our present economic conditions, producer gas power is justly limited to the sizes under 1 000 horse-power, roughly, unless propitious factors, as high loading and high fuel cost, say $3 to $3.50 and above, obtain.

Interest has been revived in the oil engine in this country, not so much from developments established here as in the pronounced success which is reported to have attended the best continental designs. Like the gas engine, it will probably be restricted by commercial considerations as to the sizes to be employed. Oil engines are, in many respects, very attractive, but the various engineering journals have heretofore correctly sounded a note of warning as to unrestrained enthusiasm; that is, the experience necessary in building Diesel oil engines is so widely different from that required in manufacturing steam engines. And that, consequently, if this fact is disregarded, the fresh impetus lately given the oil engine will be upset by dismal failures which are bound to ensue and which will plainly retard its progress. A valuable lesson of this character was acquired in gas engine and producer work, and we note, not only retrenchment, but some manufacturers are withdrawing from the field.

Reciprocating steam engines have bid for renewed favor with some radical changes in design,—the unidirectional flow type, use of poppet valves, and superimposed engine and boiler construction. These modifications obviously attract attention, but they are not to be regarded as novel, since, in every case, these late departures are simply elaborations of various designs devised many years ago.

It is true, possibly, that they will become a small factor in power work, but these revisions in reciprocating engines are not to be taken too seriously, as they are in opposition to the natural inclination toward "rotational" machinery. Although Americans lead in the building of large power units, they are now only following in the trail of foreign contemporaries in a more general use of the centrifugal types of power plant auxiliaries, and among which should be principally mentioned the rotating air pump, which abroad has become a prominent feature in the various condenser installations for stationary and marine work.

PROGRESS IN RAILWAY SIGNALING

HAROLD McCREADY

LOOKING at the matter from the selling standpoint, railway signaling has been rather dull during the past year. Only a comparatively small amount of new work has been done by the steam roads on account of the conservative attitude of those responsible for their management. This lull in construction, however, has given both signal engineers and manufacturers an opportunity to invent and develop new schemes and apparatus which will undoubtedly be of great value.

Perhaps the most interesting development in railway signaling is the application of alternating-current track circuits and block signals to interurban electric roads. The remarkable growth in the trolley road field during the last few years has resulted in a service, which, in many respects, is comparable to that of steam roads, especially as regards speed, frequency of service and character of rolling equipment. Many interurban lines are now operating two, three and four car passenger trains at speeds of forty miles an hour, as well as local freight trains. When one takes into consideration that practically all interurban roads are single track, it will be realized that the simultaneous operation of heavy, fast passenger trains and local freight trains, without block signals, is a ticklish matter. Railroad people have come to realize that protection is necessary, and, as a result, some important installations of block signals have been made during the year.

The earning capacity of interurban lines in general is not such as would justify the installation of a very complex and expensive system of signaling, nor is it necessary. Much work

has been done toward simplifying steam road signaling to bring adequate protection within the range of interurban lines. For example, light signals will probably be used instead of the more expensive electric semaphores commonly seen on steam roads; in some cases the indication of the light signal is not so distinct as the semaphore, but the use of large, well illuminated colored lenses, well hooded to protect them from sunlight, has made the light signal quite reliable in its field. Some ingenious circuit schemes, embodying the use of interlocking and stick relays, have been devised to allow of following but not opposing moves. A considerable amount of signaling will undoubtedly be installed on trolley roads during the next few years.

The application of alternating-current block signaling to steam roads is now being given the most careful consideration by signal engineers; in fact, a few important installations have already been made, and one of the great eastern roads has even decided that all new work shall be done on the alternating-current basis. So many advantages are offered by the alternating-current system in the way of power transmission, low cost and ease of maintenance, etc., that it must eventually displace the direct-current battery system on all important steam lines.

It is a noteworthy fact that the four most important installations during the year have been alternating-current systems, viz: The Illinois Traction System (500 volt, direct-current propulsion), the Southern Pacific (1 200 volt, direct-current), the New York, Westchester & Boston (11 000 volt, alternating-current), and the Santa Fe (steam road).

Few realize the great advance made in the manufacture of signal apparatus through the application of improved moulded insulations. Insulations broken down by heat, lightning, oil, or moisture have often caused grounds leading to false clear signal failures; fibre, hard rubber, insulating paper, etc., seem to be especially affected by the above influences. The invention and commercialization of phenolformaldehyde compounds, such as Bakelite, Condensite, etc., have opened an entirely new field and we now have moulded insulations which are heat, moisture and puncture proof over a wide range.

Increased attention is being paid by railway signal engineers to the purely technical features of their apparatus; most orders received nowadays are accompanied by specifications cov-

ering not only safety features but also operating characteristics. This statement, which applies to all classes of apparatus, is significant, as it indicates that the signal engineer is rapidly making himself as proficient technically as he has been practically for many years.

ON THE METHODS OF NOMINATING AND ELECTING OFFICERS IN THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

GANO DUNN
President

AT the last annual convention of the American Institute of Electrical Engineers, a session was given over to a conference of Institute officers and Section delegates for the purpose of discussing reforms in the methods of nominating and electing officers, so that these might more truly represent the Institute as a whole than it was considered they do at present. A reading of the Proceedings of the session—which have been printed and sent to those taking part—indicates two principal topics of discussion, with divided opinion upon each. They are: 1—whether or not every election shall be a contest, and 2—whether or not a member of the Institute, resident outside of New York, has his full voice in the Institute's affairs.

In the writer's opinion, the answer to the first question is a matter of taste. In the politics of our country, from the election of a mayor to that of a president, we are accustomed to contests; and in clean and well-defined contest there is nothing but good health for the state. There are those, however, who feel that in a professional body, in which, relatively speaking, there are no material interests involved, and in which an office is solely an honor, different considerations should apply. To these, even a friendly contest over an election appears undignified; their attitude is that an honor should seek the candidate, that the honor is lessened if it be not unanimous, and that one or the other of the candidates must necessarily be placed in the position of seeking the honor if he does not withdraw in favor of his associate.

In the professional and learned bodies of Great Britain and the Continent, contests are practically unknown, and nominations are left in the hands of representative committees, that discuss the merits of various candidates and select one of them, the assumption be-

ing that since the nominating committee is provided for in one way or another by the members, the representative men of which it is composed would bring to the selection of candidates the same principles that would govern the members themselves if the selection were general.

Literally speaking, the principle of uncontested elections was adhered to by the American Institute of Electrical Engineers until the last revision of the constitution, when a provision was inserted permitting two members of the Board of Directors to call for a contest. The Institute had gone along on the theory that its Board of Directors, for the election of which every member and associate has a vote, was representative of those members and associates, and, consequently, was a trustworthy nominating committee. Before the last revision of the Constitution, there were only two occasions when its choice of nominees was seriously questioned, and on those occasions its choice was, after all, ratified by the membership.

While the Board of Directors, as a nominating committee, had discretion not to be bound by the nominating votes of the members (these being, according to the Constitution, in the nature of a "straw" vote to give some guidance to the Board), there came to be an unwritten law in respect to the office of President that the candidate receiving the highest nominating vote should be the choice of the Board. When this unwritten law acquired authority, it practically turned the nominating ballot into the electing ballot, and left the Institute without a nominating committee in respect to the Presidency. This drew forth constantly increasing electioneering in favor of various candidates, and at the time of the last revision of the Constitution the unwritten law was transformed into a written one, and it was made practically compulsory upon the Board of Directors to nominate for the Presidency the candidate receiving the highest nominating vote. There was then inserted the provision that, on the request of two members of the Board, a minority candidate should be put upon the Directors' ticket, in order that contests might be permitted. These contests, however, have been only twice called for—the first occasion four or five years ago, when the minority candidate was elected; the second occasion during the last year, when the minority candidate was defeated.

While, by the last revision of the Constitution, the function of the Board of Directors as a nominating committee was taken away in respect to the office of President, it was left in respect to the offices of Vice-President and Manager; in consequence of which the

Directors have not always placed in nomination the men whose names have had the highest number of nominating votes. It has used its discretion and has occasionally departed from the showing of the list, usually to choose a non-resident candidate, notwithstanding his smaller vote, in preference to a resident candidate with a larger vote; or as between two non-resident candidates, the one who could best represent his constituency by a reasonable attendance at the meetings of the Board.

The provision permitting a contest to be called for in the election of vice-presidents or managers has not been called into use, there never yet having been even two members of the Board who sufficiently disagreed with the choice of the majority as to call for minority nominees.

Coming now to the second question: There is complaint of the preponderating influence of the eastern membership. There is the same complaint in regard to preponderating influence of the eastern states in our national government, with its capital at Washington. The large majority of the membership is in the eastern states, and it is principally in consequence of this that there are more representatives from them on the Board of Directors. It is undoubtedly true that representatives from the Pacific Coast, and from the mountain states, have been unusual on the Board of Directors, and when on the Board have been unable to represent their territories by attending meetings. The necessity for attending meetings is very real; and unless a quorum is present the Institute's work is blocked. Unless the Constitution is changed to permit the conduct of the Institute business by correspondence and letter-ballot, the necessity for attendance will continue, and if, as has been suggested, a Constitutional amendment should provide for absentee voting and the conduct of the affairs of the Board by mail, with the control of active affairs left in the hands of an Executive Committee with headquarters at New York, the result would undoubtedly be gradually to take away from the Board as a whole the principal conduct of the Institute's affairs which it now has, and to place it in the hands of the Executive Committee. A reading of the resumes of the work done by the Board of Directors, published in the electrical press after each meeting, will show clearly the very large amount of important business transacted, most of which would gravitate to an Executive Committee if the slow and difficult process of transaction of business by correspondence were introduced. The writer believes that the

handling of its business by the whole Board instead of by a small Executive Committee has been one of the sources of the Institute's strength. Such an Executive Committee would of necessity be composed of members who could attend its meetings, and would in turn be open to the charge of not having upon it representatives of the distant constituencies of the Institute. In the writer's opinion, the remedy of letter-voting would satisfy only an ideal and would not be a real remedy.

Some of the Section delegates feel that nomination of officers by delegates would give the distant members greater and more effective representation, a plan having been proposed whereby every seventy-five members were entitled to send one delegate to a nominating convention. It is not clear how this would alter the present situation; in fact, it appears more likely that the plan would reduce the representation of the distant members, since for each group of less than seventy-five members there would be no representation at all. The real difficulty in representation seems to be at present that the membership does not care enought about nominations to vote. Only twenty percent of the membership exercises its privilege. And in the case of manager, at the last election this small percentage of the total vote was scattered among 581 candidates, when there were only four candidates to be elected, and the candidate receiving the greatest plurality received only 4.8 percent of the total vote of the membership. A number of candidates received nearly the same vote, so it is not unreasonable to expect that the Board of Directors, from among so many candidates for nomination, should exercise the discretion vested in it by the Constitution and assist the membership in making selections.

Without attempting at this time to solve the whole problem, the Board of Directors has taken a step in the right direction in an endeavor to secure representative nominations by concentrating upon a few candidates the scattering vote, so that the will of the membership might be more clearly expressed. When nominating ballots have been sent out in the past, there has been nothing to guide the recipient as to who was a suitable person to receive his nomination; but in the future there will accompany the nominating ballots a statement of the names of all nominees in whose favor there has been received at the office of the Secretary of the Institute, prior to January 25th of each year, fifty or more endorsements by petition or individual letter. With the names of these candidates for nomination before

a member he is likely to cast his ballot for one of them, and consequently, the bulk of the nominating vote, instead of being distributed among over five hundred candidates, will probably be distributed among, say, a dozen, resulting in a clear indication to the Board of Directors of what is the will of the membership.

It is perfectly possible for distant members to band together and concentrate upon a candidate without the method of nomination by delegate, and it would, in fact, be more effective; and it is to be hoped that the method of advance nomination by petition, which the Institute has just adopted, will enable distant groups of members to select a man who can attend at least a part of the meetings and to concentrate their votes upon him if they desire to send him as their representative to headquarters.

THE NATIONAL ELECTRIC LIGHT ASSOCIATION

JOHN F. GILCHRIST
President

A REVIEW of the work of the National Electric Light Association during the current year shows a steady maintenance of interest and progress. The growth of the Association continues at what may be considered now a nominal rate of 30 or 40 percent a year. At the annual convention, Chairman H. H. Scott reported the records of the Membership Committee to show a total of 8 665 members on May 30th. The same committee now reports a total of about 10 150, so that the association will enter the new year not less than 10 250 strong. Large accessions are already expected in the Commercial and Power Transmission Sections, and several new company sections have been formed or are now organizing. Since the annual convention the Northwest Association has affiliated, bringing in the great States on the Pacific coast, and during the past month the Michigan Electric Association has also become part of the body.

The growth has been well distributed as to locality, but it is expected that for some time to come accessions may be largest throughout the far west in view of the intention to hold the next annual convention at Seattle, and the great interest which is being manifested in this convention of next June.

The literature of the association commands increasing attention, and the plans have been laid for many valuable additions to the books and manuals issued by the association. The revision of the *Question Box 1902-09* has been printed and will shortly be

issued to the membership entitled to receive it. The Report of the Overhead Line Construction Committee presented at the last convention has been in remarkable demand throughout the entire electrical industry and has been accepted as standard in the various branches of outside electrical construction.

The Commercial Section has issued two practical pamphlets during the year, and now has in preparation for its members a digest of all the data and literature of the last four or five years in relation to commercial work of every kind. The Meter Committee has in hand the preparation of a Meterman's Handbook or manual, and the Rate Research Committee is making a thorough study of the matter available in regard to electrical rates with the object of issuing a compilation on the subject.

The Commercial Section has taken hold of its work for the year very vigorously, and in order to secure the best conditions of development has opened offices in the main headquarters of the association. The secretary of the Section is installed there with a working staff, and a great deal of useful work of a general character and on behalf of the twelve special committees has already been put in hand. Another feature of the association work which promises to be of great importance during the coming year is that of the Resuscitation Committee, which has now succeeded in effecting preliminary measures for the appointment of an authoritative medical commission which will investigate the subject and report to the association on the best method of resuscitation. This report, through the government and various allied engineering bodies will then be rendered available to the American public, the whole work being done under the control and financial support of the National Electric Light Association.

The Public Policy Committee of the association is following up its momentous work of last year in the further development of welfare plans, and is now making an investigation as to what welfare work is being done by every member company in the association. The results of this study will be reported at the Seattle meeting. The committee is also making a study of the present conditions relating to municipal ownership, and is giving assistance to member companies confronted with this problem of socialistic propoganda. In the meantime the office of the association has undertaken the collection of specific data relating to the subject, and has also laid the foundations for a library in which are deposited

for ready reference all the current records of the twenty-five or thirty Public Service Commissions or kindred bodies now established for the supervision of central stations and other public utilities.

NEW CANADIAN DEVELOPMENTS

N. S. BRADEN

THE year 1911 has been signalized in Canada by the placing in operation of very important water-power developments and distributing systems. Perhaps the most important has been the new development of the Shawinigan Water & Power Company, Shawinigan Falls, Quebec, which now has in successful operation two of the largest water-wheel type generators which have ever been built on this continent, these generators being of 14 000 k.v.a. capacity. The transmission line also employs the highest voltage used in the Province of Quebec, the transmission being at 104 000 volts, and the length of the steel tower line eighty-three miles, supplying power to the electric railway and lighting industries at Montreal.

In Ontario the extensions of the 110 000 volt hydro-electric system taking power from Niagara Falls have continued until now there are nearly three hundred miles of 110 000 volt line in operation, supplying over twenty towns and cities, with prospects of further extensions during 1912.

In the northern part of the province, the Porcupine mining district has already in operation a four thousand horse power hydro-electric development, the power being obtained from the Metagami River, which empties into Hudson Bay, this being the first power development to utilize the northern water-shed in Eastern Canada.

The City of Winnipeg has also placed in operation a new hydro-electric development consisting of an installation of some 30 000 horse-power, transmission at 60 000 volts for a distance of seventy-seven miles from Winnipeg River to the City of Winnipeg, where the power is used for various public and private installations.

Further west, the City of Calgary is being supplied with power by the Calgary Power Company from their hydro-electric development on Bow River in the Rocky Mountains.

The design, manufacture and installation of the apparatus used in the above plants have been carried out successfully and with

one exception by Canadian manufacturers. In many cases new and difficult problems were presented, and the fact that such problems have been successfully solved by the local manufacturers speaks well for electrical progress in Canada.

THE PRESENT TENDENCY IN INDUSTRIAL EDUCATION

C. R. DOOLEY

THERE is hardly a locality that is not interested in some phase of training for service. Just now there are many plans, each peculiar to its local surroundings and each presenting many satisfactory elements, but industrial training is so new in the United States that general tendencies are not well defined.

When our present public school system was established it was so far ahead of its time and it worked so well that the public mind called it a perfect thing and paid it reverence for many decades. The boast of our country has been our public school system. Men of affairs sought young graduates through a sort of faith that their training, regarding which they themselves knew nothing, would exactly fit them for active work. The failures were attributed to a certain inevitable percentage.

To-day business men have a new interest and are not only ready to assist teachers, but are operating schools of their own. "Education for Efficient Service" instead of for classified knowledge is the most general tendency. It is the man of affairs who is bringing about this change. One proof of this statement lies in the fact that, at the recent annual convention of the Society for the Promotion of Industrial Education, held at Cincinnati in November, most of the principal offices, including the presidency for the coming year, were filled by business men. The outgoing president and many of his associates were also business men. This society, which is but five years old, is probably the leading exponent of industrial education in the United States and is doing much in the development of the cause. It should not be inferred that the professional school teachers are unequal to the occasion. They are working in harmony with the general movement and they are making every effort to measure up to the new standard, but it has fallen to the business man first, to see the light and take the lead.

Whether or not a uniform system of industrial training will be developed, similar to that of Germany, the future only will tell. In

the meantime the various efforts may be classified under four general heads: Municipal schools; coöperative schools; shop schools, and trades schools. Schools of each of these types are scattered all over the Central and Eastern part of the United States, oftentimes occurring in the same cities. This would seem to indicate that we are a long way from standardizing industrial training. The advisability of such a standardization is another question concerning which much valuable information can be had from studying the methods which Germany has developed.* In general, schools of all of these types are doing good work and the enthusiasm of their leaders would seem in itself to indicate that the fundamental principle has come to stay.

A few of the states have enacted laws which are almost revolutionary in character. In this respect Wisconsin heads the list. Among other things its new school law compels all cities of 5000 inhabitants and over, to establish and maintain at public expense trades schools, vocational schools, commercial schools and evening schools. It further requires all children between the ages of 14 and 16 who of a necessity must seek employment to attend school five hours per week. The burden of this responsibility is laid upon the employer and the states see that it is enforced. Ohio has recently passed a similar law and its operation in Cincinnati is meeting with general approval.

The number of shop or factory schools, throughout the country, far exceeds our knowledge. Boys and girls are quietly being trained by industrial establishments for their own needs, though the training they provide covers a broad field of fundamentals. Wanamaker's store in Philadelphia almost duplicates the elementary public school work and in addition furnishes a military training which, added to the regular store service, provides a course in discipline which perhaps no public school could duplicate. While the whole course is pointed toward the final object of either selling or purchasing goods, it is interesting to note that it is primarily based upon a training in the common branches, discipline, strict attention to duty, courtesy, etc. With these characteristics once well established, technical knowledge and ability follow easily.

Self interest is hardly the right word by which to characterize the educational work of an industry. In a broad sense it is the true

*See Bulletin No. 14 of the Society for the Promotion of Industrial Education.

end in view but in no sense is it the means by which to gain that end. The Fels-Naptha Soap Company of Philadelphia presents a striking example. Since this factory makes nothing but soap and only one kind of soap, it has very little use for a mechanic or for men of skill in any particular trade. The management feels, however, that it would not be fair to the community to employ young men between the ages of 16 to 18 and keep them at a monotonous routine job for possibly ten years at the end of which time they would have no training which would do them any good in any other line of work. This Company therefore equipped a machine shop which will accommodate 10 to 15 men and which they will use for doing odd repair jobs in addition to instructional use. The Company now makes this proposition to all young men in their employ:

"If you would like to learn the machinists' trade we will give you one week a month in the machine shop and two evenings a week in the drawing room. We will pay all expenses of this school and will pay your wages for this week just the same as the other weeks. You must agree, however, that at the end of the three years, when you have completed the training which we offer, that you will leave the employ of this company and follow your trade."

The old undirected apprenticeship system is giving way and while the end in view is the training of men for a specific service, yet the most successful efforts are those based upon humanitarian views recognizing the human nature of the boys and the value of character building.

The next few years will see an entirely new type of teacher in the school. He is now fast becoming a man of at least practical sense, if not actual experience. He can do three things well—First: Explain the theory of fundamental science. Second: Demonstrate its application to the ordinary things of daily life. Third: Size up the capacities of his students and give them individually, sound advice.

The new system of training will not limit the height to which any student may climb but will allow him to step off at his proper level, thoroughly imbued with the idea of efficient service and fully equipped with fundamental science up to the limit of his capacity. The business world is taking the lead in this movement because it is forced to, yet the problem is clearly one belonging to the public school system and must reach a final solution through popular legislation if the United States is to maintain its industrial supremacy.

PROGRESS IN ARC LAMPS AND ILLUMINATION

C. E. CLEWELL

THE year 1911 has witnessed improvements in the designs of existing types of arc lamps as well as a radical departure by the introduction of a new type to an already long list of efficient illuminants. The vast proportions of the arc lamp field require an increasing supply of lamps to fill the needs of city and suburban street lighting, the illumination of large factory areas, railroad yards, warehouses, and the like. The year has also been notable on account of the increase of interest in the application of scientific principles to the illumination of streets, parks, public areas and the industries. This has been accompanied by a marked attention to the requirements of illumination for all purposes, by an extended use of electric lamps, and also by an analytical study of street and industrial illumination.

The simplicity in construction, lightness of weight and neat appearance, coupled with high efficiency, of the standard line of enclosed carbon arc lamps of the alternating and direct-current types for constant potential and constant current circuits, as well as the direct-current series multiple lamp, has caused them to retain a large measure of popularity with the trade for certain purposes, in spite of the radical and far-reaching developments of new types.

Arc lamps using electrodes of a metallic character instead of carbon, and known as the metallic flame type, although comparatively new, have been accorded a demand of large proportions in the few years since their introduction. The high candle-power of this lamp, its broad light distribution, together with a long electrode life, make it a lamp notably adapted to street lighting. The principal changes in lamps of this type during the past year have been a reduction in weight and improvements in the design of glass globes for obtaining the most favorable light distribution. The metallic flame arc lamps of the multiple and multiple-series types for constant potential circuits and the series type for constant direct-current circuits have a large field and their use during the past year has shown a large increase over the previous year.

The most significant and important development, however, in the arc lamp field has been the introduction during the past year of a long-burning, impregnated carbon, flaming arc lamp. The impregnated carbon flaming arc lamp with its characteristic yellow penetrating light has been familiar for some time. Its distribution

and large volume of light have adapted it in an exceptional manner to industrial illumination where relatively high mounting is necessary, as well as in other locations. The one objection in the past to lamps of this type has been the very short life of electrodes, sometimes as low as six or eight hours. This new lamp possesses the quality of high candle-power similar to older types of carbon flaming arc lamps, but has in addition the excellent feature of long life of electrodes, the lack of which, as stated, was one of the greatest disadvantages of older types. Various colors of light are obtained by different treatment of the carbons. The yellow color has seemed best adapted to industrial conditions where a very penetrating light is required for dark surfaces. The white light is better suited to street illumination, although obtained at a slight sacrifice in efficiency. The light distribution of this new lamp adapts it in a superior manner not only to exterior areas, but also to industrial work, and the field of the carbon flame arc lamp will be greatly broadened and its use given a large impetus.

The improvements in arc lamps during the past year or two have made the gap between arc and incandescent illumination even greater than before. Those who see a complete substitution of medium-sized lamps of the incandescent type for all other illuminants should view the situation from the standpoint of existing facts. Small and medium-sized lamps of all types undoubtedly have done much for the illumination of areas which, due to low ceilings, have been illuminated with difficulty in the past by lamps of high candle-power. There is, however, but little conflict between the arc and the incandescent lamp in that each has a clear and distinct field of its own. The importance of large lamps can therefore hardly be over-estimated.

During the past year or so, there has been an attempt to determine standards for street illumination. Definite spacing distances of lamps on city or suburban streets is practically a new thought. The difficulties in following rules for street lamp spacing are great, due to objection against placing lamp posts at arbitrary locations along the thoroughfare, irrespective of crossings or corners. Furthermore, the almost unlimited diversity of existing spacing distances of street lamps might well discourage any efforts to define the advanageous spacing of lamps according to certain illumination principles.

Notwithstanding these difficulties, a study, commendable as

far as it has gone, has been made of existing conditions. This study has included the features which will promote higher efficiency, and has shown the spacing of lamps to be larger than can yield even an approximate uniformity of illumination along street surfaces, and also glare to be detrimental to the efficiency of vision along streets at night. A form of distribution curve for street illumination has been suggested as most favorable in reducing this glare and a spacing distance between lamps equal to four times the mounting height as most economical in the use of a lamp with this hypothetical distribution. These statements may, or may not, receive the endorsement of engineers who are devoting their attention to street illumination. They are, however, in a progressive direction, and, therefore, entitled to attention, even if not endorsement.

The new ideas promulgated during the past few years tend towards the adaptation of carefully designed lamps, equipped with suitable reflecting devices, to certain spacing and mounting conditions, as well as towards a more liberal use of lamps for given street and factory areas. The results are already beginning to be felt in greater uniformity and higher intensities of illumination.

There is a tendency in some localities to use large numbers of small lamps along the street or roadway. Satisfactory illumination can, however, be obtained by using increased mounting heights and greater spacing distances, provided the ratio between these factors is properly maintained and the lamps possess suitable distribution characteristics. A large number of small units are open to criticism. A large number of closely spaced lamp posts along the street or driveway may be unseemly, and the glare due to low mounting heights and poor light distribution objectionable. Arc lamps when scientifically designed for light distribution at useful angles, are adapted to comparatively large spacing and high mounting. Consideration of large units is, therefore, a wise course before hastily adopting a scheme of small lamps, which may be more a novelty of temporarily pleasing appearance than a matter of scientific and practical illumination excellence.

ELECTRICAL WORK BY THE UNITED STATES GOVERNMENT

D. S. BOWMAN

ELECTRICAL engineering works as carried out by the Federal Government have during the past year been confined principally to the activities of the Navy Department, the Reclamation Service and the Panama Canal.

The year has witnessed the commissioning of the battleships "Florida" and "Utah", each of 21 825 tons displacement and 510 feet in length, and the completion of about forty percent of the construction work on the battleships "New York" and "Texas", each of 27 000 tons displacement and 565 feet in length. These vessels have been or will be equipped with turbine-driven generators for lighting and general power service. Electricity is used for manipulating and controlling the big guns, for ammunition hoists, for searchlights, for ventilation, for steering gears, automatic signaling, cooking and numerous miscellaneous purposes. Plans have also been completed and bids invited for two 30 000 ton battleships, each of which will have a full complement of electrical equipment. Practically all mechanical operations on shipboard are now being successfully performed electrically, with the single exception of ship propulsion. It is understood that the Navy Department contemplates advertising soon for bids on a gunboat with the usual electrically operated equipment, the interesting feature being that proposals on alternating-current apparatus will be considered. This recognition of alternating current for navy service is a decided departure, the advantages of direct current for special motor applications and searchlights having held back this development.

New dry docks of size sufficient to handle the largest battleships are now being built at the navy yards at New York, Puget Sound, and Pearl Harbor, Hawaii. Contracts have been closed for the complete pumping outfits for these docks, the large pumps and valves to be controlled and driven electrically. At the Norfolk Navy Yard the steam driven pumping machinery on two of the older docks is now being replaced by large electrically driven pumps. This change will increase the economy and reliability and facilitate the operation of the dock.

The noteworthy tests with the new marine turbine reduction gear on the collier "Neptune" have been practically

completed. These tests have demonstrated the entire practicability of this gear, by means of which the high-efficiency, high-speed turbine can be used to drive the screw propeller without sacrificing its efficiency which is best at comparatively low speeds. In contrast to the new reduction gear, which provides mechanical means of speed reduction, thereby better adapting the steam turbine for marine service, the Navy Department is now building the collier "Jupiter", which will have its main shafts electrically driven by large, slow-speed induction motors receiving energy from high-speed, turbine-driven generators. The tests on this ship will be followed with deep interest by engineers as they will afford the first real opportunity to compare the efficiency and practicability of these two schemes of adapting the high-speed turbine to the low-speed propeller.

To facilitate the handling of ships' armament, contracts have been awarded for two large floating cranes of 150 tons capacity each, for use at the navy yards at Boston and Pearl Harbor. Each of these will consist of a large stationary type gantry crane mounted on a suitable pontoon. Electric operation will be used, power being furnished from an engine-driven generator installed on the pontoon.

A complete new turbine-driven central electric power station is now being built at the Pearl Harbor (Hawaii) Naval Station, and many additions and improvements have been made in the central power stations at most of the other navy yards.

The Reclamation Service has continued its great work of reclaiming western arid lands and has, during the year just past, awarded contracts for several power stations of fairly large capacity. One of these on the Rio Grande project in Texas and New Mexico is a steam plant in which turbine-driven units are to be installed. The power thus generated will be used for operating the heavy cable-ways, derricks and hoists used in the construction of a large dam. On the Boise project, Idaho, and on the Truckee-Carson project, Nevada, equipments for hydro-electric plants have been purchased. These will be used temporarily for construction work and will later furnish power for operating motor-driven irrigation pumps. During the past year the power transmission lines on several operating projects have been extended and many motor-driven pumps, some of quite large capacity, have been added. The Reclamation Service carries on its work so quietly that the magnitude of its engineering

undertakings and the economic importance of its operations are not generally realized.

The Panama Canal is probably more in the eyes of the world than other government works of an engineering nature. Reports of progress are carefully read and discussed. Usually these reports concern the progress of excavation, concreting, etc., but to electrical engineers the special operating machinery is of no less interest. Upon the development and proper construction of this machinery will depend the safe and speedy navigation of the canal and operation of the locks.

A contract has been awarded for the emergency or movable dams. These are virtually huge swing bridges which can be thrown across the canal above the locks and from which girders and gates can be lowered into position at the entrance of the locks, thus checking the flow of water in case the other lock operating machinery should become damaged. These will be electrically operated and controlled throughout. The large valves, which will normally control the flow of water in the locks, are being built and plans for the machinery to operate the miter gates have been completed. This apparatus will also be motor driven.

The climatic conditions on the Isthmus are almost unbelievably severe upon machinery and upon electrical insulation in particular. In order to determine the suitability of the electrical apparatus offered, trial orders for motors have been given to three prominent manufacturers of electrical machinery. These motors have been undergoing severe tests on the Isthmus for some months. These tests are being held in secret, but it is generally understood that extreme conditions of overload, over-voltage, temperature and moisture are being imposed on the motors.

The Canal Commission has received proposals for the hydro-electric plant which will furnish to the motor-driven lock machinery, power to be generated from the waste water at the spillway of the Gatun dam. Bids have also been received for forty special electric towing locomotives or mules, it being the intention to permit ships navigating the Canal to proceed under their own power only through the channels outside of the locks.

Under the supervision of the War Department, the Government of Porto Rico is carrying out preliminary plans for irrigation. Equipment for a hydro-electric plant has been pur-

chased and motor-driven pumps will be installed in order to determine the practicability of applying irrigation to Porto Rican conditions. If this proves as satisfactory as anticipated the work will be extended.

On the whole, while the past year has not been epoch-making so far as Government electrical engineering works are concerned, considerable progress has been made, and the examples mentioned will serve to call attention to the remarkable engineering works continually being fostered and carried out by the United States Government.

NOTES ON ELECTRIC RAILWAY PROGRESS

THE recent developments in the railway field were reviewed in the October issue of the JOURNAL. There are, however, a number of additional items which should be of interest.

One of the features of the more recent type of single phase cars for the New York, New Haven & Hartford Railroad is the simplified control equipment for operation on both alternating and direct current. The main difference between this and the earlier types is the use of resistance in place of preventive coils for passing from notch to notch of the controller, resulting in lighter equipment and fewer switches, as most of the alternating-current switches can thus be used when running with direct current. The New Haven road has also placed in operation a type of switching locomotive, operating on alternating current only, in which the control is, of course, greatly simplified over that adapted for operation on direct current as well. The two new types of locomotives which are being operated on fast freight and heavy passenger service differ in their electrical equipment mainly in that one has four main motors and the other eight, operated in four sets of two each. The twin motors are connected permanently in series and the pinions of the two motors of each set are meshed with a single gear on the driving quill. The four-motor locomotives, when operated on direct current, require connection of the motors four in series on the starting position and two in series on the running position for series-parallel control, while on alternating current the motors are operated in multiple. It will be seen that this complication of control for direct-current operation is

obviated in the case of the eight-motor locomotives, which results in a corresponding simplification of the equipment. The other principal mechanical features which distinguish the eight-motor engines from the four-motor type are the single cab with its rigid frame and the flexible truck mounting. One of the electrical features of the later New Haven locomotives is the adoption of two-coil transformers in place of the auto-type, which makes it possible to operate the motors on an ungrounded circuit.

On the single-phase cars of the New York, Westchester & Boston Railroad the control is suitable for operation on 11 000 volts alternating current only. For their control but seven unit switches are required.

The successful use of motor field control, first on certain of the New Haven locomotives in direct-current operation, and subsequently on the Pennsylvania Railroad locomotives, has resulted in the development of a standard type of control equipment for the application of this feature to ordinary railway motors for both slow-speed city service and high-speed interurban work. Tests indicate a very substantial saving in power in city service as well as a superior speed control for interurban service on cars equipped with field control.

It is evident that there has been a strong tendency toward the use of lighter weight equipments in all railway service as shown in the design of control apparatus, motors, car and locomotive bodies. There is some danger that this tendency may be carried to an extreme which will result in very high maintenance costs which will overbalance any saving. The prime object of reduction in weight is to reduce the power consumption. It should be remembered that other considerations than weight affect power consumption, and if light weight is secured by an inefficient motor speed or gearing, the net result may be an increase in power consumption. These points should be kept in mind and the greatest conservatism used in reducing all weights.

In mining work the commutating-pole motors find an important place as a means of meeting the exacting and severe service involved. Appreciation of the importance of a design of mining locomotive which will give accessibility to both motor and track equipment is evidenced by the more recent construction. As the natural tendency to inspect is proportional to the accessibility for so doing, this feature is especially advan-

tageous. One feature of locomotive construction which is favorable in this direction is the introduction of an open, cast steel bar frame which gives superior strength with minimum weight, and also aids in the matter of accessibility as well as the radiation of heat from the motors and resistances, which is obtained as a result of the more open construction. Another development in mine locomotives is that of an especially low type for operation in mines where thin coal veins are found, thus making possible the reclamation of coal from veins otherwise too thin to be worked commercially.

The first year of regular service in electrical operation of the New York terminal division of the Pennsylvania Railroad was completed in November. A review of railway activities for the year would not be complete without some detailed reference to the record of the first year's operation of this electrification. In the first place, it is interesting to note that some seven hundred and fifty employees are required at this terminal solely in connection with the operation of trains and accommodation of patrons. Furthermore, during the first year of operation over one million, nine hundred and twenty-nine thousand tickets were sold; approximately one and one-half million pieces of baggage were handled, not to mention the hundreds of thousands of parcels which were checked. Incidentally, some three hundred and seventy-eight thousand telephone calls were answered by the bureau of information—more than one thousand per day. During the year, in which approximately ten million passengers used the station, there was not a single serious accident on the entire terminal.

The official records show a total of 176 180 revenue trains operated at the terminal station. Of these electrically propelled trains, 99.59 percent were on time. The total locomotive detention in actual time for the year was ninety-eight minutes; the total number of delays was thirteen. The delays due to motors or control apparatus numbered five with a total detention of thirteen minutes. The mechanical and miscellaneous delays were eight in number, with a total detention of eighty-five minutes. These facts are especially significant when it is known that these high-speed locomotives, which are equipped with two 2 000 horse power motors, are operated daily on probably sixty percent greater train weight than was called for by the specifications, and are maintained on a

2 500 mile inspection period. The maximum recorded draw-bar pull is 79 200 pounds. This record, supplemented by the efficiency and prompt service which has been given in all departments, speaks well for the remarkable foresight and judgment on the part of those who have had to do with the planning, construction and actual operation of this remarkable electrification.

PROGRESS IN THE FIELD OF ELECTRICALLY DRIVEN VEHICLES

BERNARD LESTER

ONE of the most notable features of progress during the year 1911 in the electric vehicle field is the active co-operation between the manufacturers of electrically driven vehicles and the manufacturers of their principal component parts, such as electric motors, storage batteries, etc., and the central power stations. This coöperation is being manifested in a broad spirit of activity in presenting to the public the merits of electrically propelled vehicles. Rapidly increasing facilities on the part of central stations for charging electric vehicles is making this possible.

In the field of pleasure vehicles the "Electric" is coming more and more to be looked on as a machine of service. Improvements in its design have not been of a radical nature, but consist of many refinements. Direct drive by means of shaft and gears has become standard with most pleasure vehicle manufacturers. Improvements in the details of construction of motors, control, batteries and chassis have led to increased mileage and decreased cost of operation.

In the field of the commercial truck the advance has, if anything, been more pronounced. In making an analysis of the problems involved in the transportation of goods and their distribution, one of the striking observations to be made is with regard to the contrast between the progress achieved in transporting goods long distances, and that progress which has been made in transporting them the short distances involved in distributing from large centers. We are all familiar with the immense progress of the railway systems in our country and the remarkable advance in railway equipment and transportation facilities. The advance of the horse-drawn vehicles, however, in

an equal period of time has amounted to very little, comparatively speaking. The horse itself has not materially increased in efficiency as a machine, and although considerable advances have been made in the art of wagon building, the total increase in efficiency of wagons and drays has not been in any way commensurate with the development of steam railway rolling stock. In our opinion the present generation is going to see an immense development in the art of distributing goods. Expensive distribution systems have become a habit with us as a people. Already large department stores, the express companies, the wholesaler and many others are making a thorough study of the systems in use and the cost of operation. Distribution and transportation engineers are coming to be men of recognized importance, and large distributors are spending many thousands of dollars in an effort to distribute goods in a more economical and efficient manner. The possibilities of the electric truck make it difficult to estimate the extent to which this agent will come into general use. Efficiency in distribution is now one of the largest problems of our towns and cities, and the electric truck will, in our opinion, be one of the greatest factors toward a solution of this problem.

THE PRESENT STATUS OF THE ELECTRIC FURNACE

C. B. GIBSON

DEVELOPMENT in electric steel refining progressed slowly at first, but at present is advancing rapidly and is being taken up by the steel manufacturers both in this country and abroad. During the past year, some elaborate experiments in the electric smelting of iron ore were made in Sweden, and the results of these tests promise to open up a new field along this line where cheap power is available. In this country, during the past year, only a few electric furnaces have been installed, due no doubt to the general business depression in the steel industry.

There are three general types of electric furnaces in commercial use at the present time; namely, the arc, induction and resistance type. The resistance type furnace is not applicable to the refining of steel. It is used in the manufacture of artificial graphite, carbide, carborundum, etc. It is also used where a fairly high temperature is desired and is employed quite ex-

tensively in laboratories and for tempering tool steels. The arc and induction types are used in the refining of steel and the smelting of various ores. In this country, the arc furnace has been taken up almost exclusively, while the induction furnace seems to be in favor abroad. At present, there seems to be no universal type of electric furnace, each one presenting certain advantages or disadvantages, which have to be carefully considered for the particular work in question.

The characteristics which a good electric furnace must possess are:—The production of high temperature for quick and complete de-oxidization and refining; minimum expenditure of electrical energy; low first cost and small repairs. At present, there seem to be differences of opinion among the advocates of the different types of furnaces as to the merits of each. As regards the quality of steel produced, practically speaking, there does not seem to be any difference which furnace is used. It appears that for such installations as are not operating continuously, such as steel foundries and mills, and not possessing Bessemer converters or open-hearth furnaces, in the present state of the art, the arc furnace has a decided advantage. Particularly as it can readily be started from cold, can easily be emptied after each charge and is easily operated from a metallurgical standpoint. Another advantage is its low first cost, also the fact that it is possible to use cheap ore, containing phosphorus and sulphur, for the production of high grades of steel, when used in conjunction with the Bessemer converter or open-hearth furnace.

At the present time there are about 160 furnaces in operation or under construction in the various countries of the world. Approximately 75 percent of these are of the arc type and 25 percent of the induction type. In the United States there are a number of large arc furnaces in operation, aggregating some 65 tons capacity. There are several small induction furnaces which are either in an experimental stage or have not been adopted commercially.

The arc furnace is generally used as an adjunct in connection with the Bessemer converter or open-hearth furnace. The molten metal is first oxidized in either of these furnaces in which the carbon, phosphorus, silicon and manganese, etc., are reduced and the metal is poured in the electric furnace, where it is de-oxidized, de-sulphurized, and re-carburated. Charging from

molten metal, it requires from one to one and one-half hours in the electric furnace to produce a good quality of steel. The power consumption varies from 125 to 200 kilowatt-hours per ton of refined steel, depending on the amount of refinement. When the furnace is charged cold, it requires from four to five hours and the power consumption varies from 450 to 700 kilowatt-hours per ton of refined steel, depending on the amount of refinement.

The application of the product of the electric furnace is varied and includes tool steel, structural steel, raw materials, high-silicon dynamo steel, locomotive tires, drawn tubes, high quality steel, steel wire, automobile steel and saws. During the year 1911, the output in electrically refined steel was approximately 125 000 tons in the United States alone.

Another application of the arc furnace, which appears to have a very large field, is in foundries which are not equipped with the Bessemer converter or open-hearth furnace. The furnace can be charged cold, and the steel poured direct into castings. It is claimed that the chemical, physical and machining quality of electric steel castings are superior to crucible steel on account of the uniformity of the output. Castings which have been made in the electric furnace are particularly valuable for automobile and railway apparatus. The absence of gas and the high temperature at which the steel can be cast, facilitates the manufacture of complicated parts which, at the same time, are perfectly sound.

The electric furnace is now used in smelting nickel and copper ore. For the reduction of aluminum ore, it has been in commercial use for a number of years and new developments along this line are taking place continually. In electro-metallurgical processes, the electric furnace has been used for a number of years in the manufacture of calcium carbide, carborundum and artificial graphite, and the furnace is being put to new uses continually. Cheap hydro-electric power has made possible the developments along this line. In particular reference to the refining of steel, it is natural not to predict what the outcome will be; but one thing is certain, the electric furnace has opened up new possibilities for refining high grade steel at a moderate cost.

THE DESIGN AND APPLICATION OF INDUSTRIAL MOTORS

J. M. HIPPLE

IN the design of industrial apparatus the most noteworthy forward step during the year has been the introduction on an extensive scale of pressed and rolled materials in motor construction to replace cast parts. This construction gives greater strength than the cast construction, and, at the same time, makes possible the elimination of practically all inactive material. The most extensive application of this design to date is found in the line of direct-current industrial motors produced by the Westinghouse Company, ranging in capacity from one to one hundred and fifty horse-power. In these motors the field frame is a rolled steel ring formed from a flat slab, the feet are pressed from heavy steel plate and riveted to the field ring, the slide rails are pressed from a single piece of steel plate and the brush holders are pressed from heavy plates. This construction has been tried out in service tests for over two years and has proven so successful that it has been extended to other lines of motors, and the introduction of these methods in motor design is generally accepted as a distinct improvement.

The use of commutating poles in direct-current motors has been greatly extended during the year. Heretofore, commutating poles have been used mainly in adjustable-speed or special high-speed motors. The extension of their use to a complete line of constant speed motors, as in the type referred to above, means much to the user of motors, and really gives the direct-current constant-speed motor a new lease on life. With the introduction of the commutating pole, commutator and brush troubles so nearly disappear that the direct-current motor becomes a very dependable piece of apparatus.

An interesting development in steel mill work is the tendency of many steel mill engineers, in laying out equipments for new mills, to specify alternating-current motors for cranes, tables, and other drives requiring varying-speed motors. It has long been the practice to use series or heavily compounded direct-current motors for these applications, taking advantage of the good inherent speed-torque characteristics of the series direct-current motor. To avoid the complication of the mixed alternating and direct-current system and to eliminate motors

with commutators many engineers now favor using wound rotor polyphase motors, even though the speed-torque characteristics are not so suitable. To meet this demand motors of rugged and massive construction and with non-combustible insulation have been developed.

Many special applications of both motors and control apparatus have been developed which cannot be described in detail. Motors of fractional horse-power have been used more widely than ever before. The growing use of motors for drilling, pumping and cleaning oil wells in the great oil fields is an interesting application. The satisfactory development of reversing motors and control for planer drive is of great value in machine shops. This development covers motors having armatures of low flywheel effect, which are geared direct to the planer driving shaft, and a control which reverses the motor with each stroke of the planer bed. The elimination of belts results in a considerable saving in operation and the ease of speed adjustment over a wide range materially increases the daily product of the planer, often resulting in 20 to 25 percent gains in output.

While the field of industrial development is too broad to cover in so brief a review, enough has been noted to indicate a decidely healthy state of progress in this line of engineering, and developments of the year have shown the way to still greater progress.

DEVELOPMENTS IN ILLUMINATION AND IN THE MANUFACTURE OF INCANDESCENT LAMPS

NORMAN MACBETH

THE development in illumination along engineering lines has been rather extended in the past year. The enormous amount of publicity given to illumination in its various phases has quite equalled that devoted to the entire electrical field. Almost every popular magazine has an article of some sort, while the regular electrical journals in which a paragraph or two was the usual order of a few years ago, now devote several pages monthly to this subject. Convention papers, discussions, and illustrated lectures or talks, are so general that those interested in the subject of better illumination must be numbered by the thousands, whereas this topic was rarely broached five years ago, excepting by a few interested individuals who had something in the lighting line to

sell. This marked progress and wide interest in illuminating engineering could only come from a solid basis of usefulness—as through the application of the new law in merchandising "Satisfying the Customer," rather than the old "Let the Customer Beware" —in a business which in this country alone means the direct sale of lighting appliances valued at over $36 000 000 per year.

In the lighting industry the illuminating engineer is a necessity in the securing of that valuable asset in any business, "good results," followed by the "good will" of satisfied customers; with customers who ofttimes do not know what they want, or, at least, do not know how to express their wants. The only wonder is that this condition was not recognized years ago. Wonderful strides have been made in the art and science of illumination, when we consider the comparatively few workers devoting their entire time to this field, and, while the general recognition of this specialty is still largely confined to a few commercial interests more directly allied with the lighting field, a remarkable interest has been shown during the past year by electrical engineers and contractors, architects and consumers, from whom a truly surprising number of inquiries have been received by the illuminating engineering departments of the lamp and reflector manufacturers. Many lamp salesmen are also taking advantage of the opportunities afforded by these departments to get closer to their consumers in the delivery of that in which the consumer is most particularly interested—illumination. Incidentally, this greater consideration of results has widened the lamp market very considerably. Intensities of two to ten times that of a few years ago are to-day recognized as necessary in many mercantile and industrial establishments.

Street illumination is beginning to receive more attention, which will undoubtedly result in a similar widening of the market for the light sources adapted to this service. Street lighting in the past has been largely a matter of a cash appropriation for the minimum number of lamps, which are often considered merely on the basis of the lamp cost, with little or no attention to the generation or distribution of the light. A few large installations for real street illumination will see the beginning of the revolution in this field.

In the manufacture of incandescent lamps by the Westinghouse Lamp Company, with which the writer is most familiar, the production of carbon filament lamps has not shown an increased demand although the output was equal to the maximum of other years.

The metallized filament lamps (in which the notable change in construction, from the double hairpin to the oval filament, was conceived and developed by this company) are now being used in greater quantities. The present favorable prices on these lamps enable many of the larger central stations to substitute them for the carbon filament lamps formerly furnished to their consumers on a free renewal basis, giving the consumer approximately 25 per-cent increase in illumination, with a useful life 30 percent to 40 percent greater than the carbon filament lamps and with practically the same renewal cost and income to the central station. It is anticipated that this lamp will gradually replace the old carbon filament lamp in a great many installations throughout this country. In the 100 volt grade, the 30 watt lamp was developed and placed on the market this year. Mention might also be made of a small bulb, 100 watt lamp, special lamps for street railway work, and also the 200 250 volt grade on which creditable progress has been made.

Perhaps the most notable development in the entire tungsten lamp field has been the recognition and adoption by all the large lamp manufacturers of the wire type—the one continuous filament. Many of the later types of lamps introduce one feature which should be recognized by those who purchase lamps for use with reflectors in which a certain definite position of the filament with reference to the reflector is essential in order to secure the correct distribution of light. The reflectors of the better grades now in use were designed for practically the same light source, shape, size and position as the earlier forms of tungsten lamps in which the filaments of the 100 volt grade are in five loops in the 25 and 40 watt sizes and six loops in the 60 to 500 watt sizes. Lamps having a greater number of loops of lesser length deviate from the standard and hence the units do not give the exact illumination results for which they were designed. Manufacturers who have lately adopted the continuous filament type of construction have deviated in many instances from the policy of standardization which has done so much to place and keep the American incandescent lamp manufacturer above his European rivals.

The production of tungsten filament lamps by this company in 1910 was on a basis 100 percent greater than the previous year and this past year's production shows an increase again of over 75 percent above that for 1910. 1911 has also seen the successful development by this company of tungsten lamps in the 200 to 250

volt grade in the six sizes of 30, 40, 60, 100, 250 and 500 watt. These lamps are excellent in every particular, and mark a distinct advance in the art of tungsten lamp manufacture.

The new 15 watt tungsten lamp in the 100 to 130 volt grade has proven in service to be a good lamp of a desirable size for many locations. The adoption of the 25 and 40 watt wire type lamps in the 100 volt grade in elevated, trolley and subway service, marks a notable milestone in lamp history.

The production of the low voltage 2½ watt sign lamps and of the street series tungsten lamps are worthy of mention, the output of the latter having been more than doubled within the last three months.

THE DEVELOPMENT OF THE CO-OPERATIVE SPIRIT BETWEEN MANUFACTURERS AND USERS

H. D. JAMES

THE general tendency to-day among the leading manufacturers, in all branches of industry, is to furnish their customers with satisfactory results, not merely merchandise. This change is taking place through a scientific study of the requirements of each customer, in order to enable him to increase his efficiency or the efficiency of the men under him.

In the field of electrical engineering these investigations are being made, perhaps to a greater extent than anywhere else, in the proper application of motors to various industries. The first steps in this direction consisted in replacing the steam engine by a constant speed electric motor belted to the line shaft. There are many good applications of this kind to-day, but a further study of the actual requirements showed that better and more economical results could often be obtained by using an individual motor for each machine. Not only did this eliminate the line shafting losses, but it gave a more positive drive and turned out more and better work. This latter application required an engineer who understood both the motor and its control as well as the power and speed requirements of the machinery to be driven.

The power plant and transmission line each entered into the problem. The characteristics of the motor and the torque required to start the load determine the maximum demand upon the generator. Where a large number of small motors is used this matter is unimportant, but one or two large motors may seriously interfere

with the proper operation of the generator. A motor geared to its load is subjected to vibration, and must stand severe stresses which are not applied to a belted motor, for the belt acts as a cushion.

These one or two references show how the engineering problems of motor application have broadened. The first step towards solving such problems is to develop engineers with the right training and experience. These men must first have a thorough grounding on broad lines so that they will understand the motors, controllers, generators, transformers and switchboards which enter as units into the problem. They must then make a special study of the requirements of the user and the results he wishes to obtain. Tests must be made and data compiled; sometimes experimental applications are made and tried out before a definite decision is reached.

One of the earliest problems was that of electric traction. Here systematic study and tests have resulted in the accumulation of much valuable data. Machine tools, cranes, hoists, etc., are other examples. The increasing demand for electric power has resulted in the building up of large central stations which require the solution of another set of application problems.

The broadening of the field has reduced the relative area which each man can cover. Engineers are now specializing on groups of applications which are closely related. We have railway, power and industrial engineers and these divisions are again sub-divided and the sub-divisions are increasing. Designing engineers likewise have been divided into groups and sub-groups.

Commercially the field is divided into three elements:—the user, the manufacturer and the consulting engineer. At first consulting engineers operated as individuals, but now many consulting engineering firms embrace a staff of engineer specialists, its size depending upon the variety of work undertaken. The services of the consulting engineer involved expense which in many cases was not warranted by the size of the work. For this reason the small user came direct to the manufacturing company for advice as well as apparatus, and the large users employed their own engineers, calling upon the consulting engineer only when in trouble or when large installations were undertaken.

The consultations with the manufacturers by customers and customers' engineers made it necessary for the former to have some sort of a consulting force to assist in the sale of their product. They

did not, however, wish to assume the duties and responsibilities of the consulting engineer for which there seemed to be no direct compensation. The customer, on the other hand, often felt that he could get a less biased opinion from an independent engineer, yet his work may not have warranted such expenditure. The consulting engineer did not always look with favor upon the manufacturers' application engineer, especially when the apparatus recommended was not strictly in accordance with the consulting engineer's specification. The lack of better coöperation between the consulting engineer and the manufacturer's specialist resulted in much special apparatus which would have been avoided by mutual concessions and as good results would have been obtained with a smaller investment.

The manufacturer and user have both found that a closer coöperation in the obtaining of data, on which to base applications, has resulted to their mutual advantage. The user gets a greater output with less labor and investment. The manufacturer gets a satisfied customer which results in quick settlements and repeat orders, instead of unsatisfactory results with their contingent expense. The larger manufacturers have organized efficient staffs of application engineers which are being increased as conditions demand and new applications arise. These men assist the salesmen by furnishing data and often accompanying them on their visits to proposed installations. Special investigations are undertaken and the operator is assisted in selecting his equipment. Where tests are required the user and manufacturer work together and share the expense. Conferences are held with large users and their engineers. Consulting engineers find that conferences with the manufacturing engineers assist in the selection of suitable apparatus at the minimum cost.

The broad gauge policy adopted by the manufacturers and the gradual changing of their organization has gone far towards business building. A set of specialists has been developed who understand the installation of the various kinds of apparatus. They have accumulated and classified the large amount of information which naturally comes to a manufacturing company. They have analyzed the many tests which are continually being made by such organizations, often arranging for special tests to secure valuable data. In short such an organization makes use of its every department to assist in furnishing suitable apparatus.

"The satisfied customer" has displaced previous mottoes in the electrical field. There is a spirit of coöperation between manufac-

turers and central station men, and both are spending time and money to make sure that the user gets the right apparatus with the least trouble and risk. Exact engineering data is replacing guess work. No one factor has contributed more to the advancement of the electrical industry than this accumulation of data and its commercial use by leading manufacturers. The men who represent the manufacturer are no longer mere traditional salesmen. They have a good engineering experience and know how to use available data. Where the problem is of some magnitude or involves unusual features, the user, having the benefit of an engineer-specialist who has made a particular study of similar installations, can feel assured that the manufacturer will use his best knowledge to supply satisfactory apparatus and will guarantee it.

The facilities offered by manufacturers for conferences with their specialized engineers, for tests and for the use of their accumulated data by the purchaser is of considerable value to both the central station and the isolated plant. The former uses these facilities for increasing his business as well as the improvement of his plant. The benefit to the latter is still more marked. The small plant operator must know exactly what power demands will be made upon his plant and how best to meet them. He has better assurance that his investment will be profitable and that there will be no delay in starting up his apparatus. Such coöperation reduces waste, insures continuity of service, and results in increased efficiency for all concerned.

PROGRESS IN GENERATORS AND ROTARY CONVERTING APPARATUS

F. D. NEWBURY

IN a similar review for 1910, attention was called to the fact that generators up to 2 500 k.v.a. normal rating had been built to operate at 3 600 revolutions per minute. It is now evident that this mark can be considerably advanced, in fact, as far as there is any advantage in space required or in steam economy.

There has been a steady advance in the application of direct-connected units of medium size. For sizes larger than can be economically built and operated direct connected, the turbine reduction gear has been advantageously used. Several 500 kilowatt and several 1 000 kilowatt units have been built or are under construction. For these units 3 600 r.p.m. turbines are generally

used with 720 r.p.m. generators in the 500 kilowatt size and 514 r.p.m. generators in the 1 000 kilowatt size, thus combining turbines and generators of the most economical speeds.

During the year the commutating pole construction has been extended to slow speed generators driven by reciprocating engines, thus obtaining in this class of apparatus the well-known advantages of the commutating pole construction.

With the improvement in the design of the 60 cycle rotary converters chronicled last year, due to the use of fewer poles and higher speed, there has been an increased demand for this class of apparatus. It is typical of this new attitude that a large railway and lighting system in the Middle West has, during the past year, adopted 60 cycle generating and sub-station equipment after 25 cycle apparatus had practically been decided upon. The use of 60 cycles obviously presents many advantages where a combined railway, general power, and lighting load must be provided for. There are also very few interurban roads which could not develop a profitable business in general power and lighting along its lines, providing 60 cycle power could be furnished economically. This situation indicates the continued increase in application of 60 cycle rotary converters for railway work.

In the latter part of 1910, commutating pole rotary converters were being discussed. During 1911, this type of apparatus has entered the commercial field. A commutating pole rotary converter with 7 500 kilowatts maximum capacity has been furnished the Interboro Rapid Transit Company, in New York, and a 1 500 kilowatt, 500 r.p.m. commutating pole rotary converter has been built for the power supply station of the Westinghouse Electric & Mfg. Company. While this speed may seem revolutionary for a 1 500 kilowatt rotary converter, the advantages gained through the use of the commutating pole permit the construction of a machine of good proportions and with no greater peripheral speed than has been used for non-commutating pole machines of the same rating with much lower revolutions per minute.

The use of the booster type of rotary converter for obtaining variable direct-current voltage in lighting work has been considerably extended during the year. A number of 1 000 and 2 000 kilowatt units have been supplied for lighting work, and three 1 200 kilowatt units have been supplied for electrolytic work. All of these units have so far been for use on 25 cycle systems. There is

no reason, however, why the same principle of voltage variation cannot be applied to 60 cycle rotary converters with equal success. It will be only a question of a short time before such units will be supplied for lighting companies, with 60 cycle power supply, which are now using motor-generator sets, since considerable improvement in efficiency and reduction in floor space, both items of vital importance, can be accomplished by this substitution.

Improvements in motor-generator sets during the year have resulted in increased efficiency, reduced floor space and reduction in noise in large sizes. Some notable sets have been furnishd for lighting service in Chicago, having a rating of 1 500 kilowatts, 250 volts, 300 r.p.m., with enclosed frames so that the air from both machines of the set can be discharged through ducts outside of the station. This results in reduced room temperature and reduced noise in the sub-station, items of considerable importance in sub-stations located in congested business districts.

Among the interesting generators supplied during the year for water-power plants have been some 3 000 k.v.a., 514 r.p.m. enclosed generators, and two 12 500 k.v.a., 300 r.p.m. vertical generators. Both of these designs employ rotors built up solidly of two-inch rolled plates, giving a construction of great strength and reliability. This construction has enabled both generators to be conservatively designed for 100 percent overspeed, notwithstanding the high normal speed.

Illustrating the opposite speed conditions, fourteen vertical generators having a rating of 300 k.v.a. at 72 and 75 r.p.m. have been supplied. The majority of these generators were for 60 cycle systems, which necessitated 100 and 96 poles. In spite of the abnormally large number of poles, these generators were built with a moderate outside diameter, an item of considerable importance in vertical generators, since the outside diameter of the generator frame usually determines one dimension of the power station building.

PRACTICAL EXPERIENCE FOR ENGINEERING STUDENTS

CHAS. F. SCOTT

"THE establishment of apprenticeship courses for engineering graduates is an acknowledgement that the output of our engineering schools is unsatisfactory." Is this statement, recently made by an engineering educator, really true? I

believe not, if it implies that "satisfactory" graduates would make such courses unnecessary. On the contrary, the technical graduate has come into general favor because he is no longer expected to be a trained practical expert when he gets his diploma, but is presumed to have a preliminary training which will enable him to acquire readily the special training and the practical experience needed in his chosen profession. There is a great deal in the industries which they themselves must furnish, which it is not only impracticable for the technical schools to supply, but which it is not their function to furnish. Their function is to make good beginners and the specialized training upon which the vitality and development of an industry depend must be fostered within the industry itself. Hence, the post-graduate course in the world's workshop is normal and proper—a logical supplement to the technical school and not a reflection upon its efficiency.

Coöperative systems of various kinds are being provided by which students may acquire practical experience before the completion of their school work. One of the latest examples is at the University of Pittsburgh, which provides several periods, each of a few months, during the sophomore and junior years which the student spends as a workman in the industries of the Pittsburgh District. The great value of this system is not that the student's technical knowledge is increased in a big practical laboratory, but that it helps to make him a better beginner after graduation. A present difficulty with many graduates is that they have so long breathed only the atmosphere of the school where the purpose of everybody is to teach them something, that they catch pneumonia in the chilly surroundings of real life where they are expected to do something for somebody else. Then there is also the seriousness of doing one thing nine or ten hours a day, week after week, instead of taking half a dozen subjects at a time in hourly doses along with as many more varied outside interests. The transition will be much easier, the graduate will be a much better beginner, if he has breathed factory air and responded to the seven-o'clock whistle in earlier years.

Many students learn what is in the book, but do not comprehend the real, physical thing. The formula is the thing they feel familiar with; the phenomenon is something which is explained by the formula. One of the hardest tasks of the teacher is to counteract this tendency and lead the pupil to think and feel nature's laws for himself. Formulæ then become merely a convenient shorthand

method of expressing them, worthy of no more reverence than the stenographer's notes of a great speech. Just as judicious laboratory exercises give definite meaning to what may otherwise be hopelessly vague and abstract, so judicious workshop or other practical experience may give definite meaning to the whole college life, making clear the rational purpose of its training in fundamental things, affording an intelligent insight into the relations between the college world and the larger world, and inspiring a new and concrete interest in one's studies as he appreciates that the college course itself is a sort of formula which stands for the things in serious, practical life. This new attitude of the student to the later years of the college work is one of the best features of the coöperative method.

Factory work will bring out clearly the serious and to some students the disappointing fact that the manufacturer is not running a shop school, but a business proposition and that they are likely to acquire more in the way of general discipline than of technical information. And it is well that this is so, for more graduates fail for lack of the ability to get along efficiently with other people than for lack of technical knowledge. Hence the value of the experience and the new point of view which early contact with working men and with real things are apt to give.

When the employers of graduates say they are "unsatisfactory" it is usually not because they are not full-fledged engineers, but it is because they are not good beginners, and coöperative methods may be made an effective means of supplying some of their important deficiencies.

IMPROVEMENTS IN TRANSFORMERS

W. M. M. CONAHEY

A SURVEY of the field of transformer engineering during the year 1911 does not show any radical changes in design as compared with 1910. The changes that have been made are mainly in the way of improvements and refinements of existing designs rather than the introduction of new types. Among power transformers, mention was made in the issue of last January of the tendency toward the use of larger units and the employment of higher voltages for long distance transmission. This tendency is still apparent and transformers are now being built for larger outputs and higher voltages than ever

before. From an engineering standpoint, there is no reason why size and voltage should not be further increased, but when the point is reached where it is necessary to ship the transformer in parts and assemble at destination, it is doubtful whether anything can be saved in cost over that of smaller units. Of course, other reasons may enter; for example, in some places the high value of floor space which will make it advisable to use very large units.

Self-cooling transformers of the tubular type have become firmly established as supplying a much needed want for oil-insulated, self-cooling transformers of large sizes. In many places artificial cooling is inadvisable or impractical, and in such cases the tubular is the only type of self-cooling transformer so far devised that can be constructed successfully for sizes of from about 1 000 to 3 000 k.v.a. In the many places that they have been installed they have proven most satisfactory and their use is increasing rapidly.

Air-blast transformers are used mainly in a few large centers and generally for the operation of rotary converters. The size is therefore generally determined by the size of the converter. Recently converter sizes have been increasing rapidly so that in the near future machines of from 4 000 to 5 000 kilowatts output will probably be in operation, and, as polyphase transformers of equivalent output will be used in most cases, a new record will thus be established for size for both rotary converters and air-blast transformers.

The condenser type of terminal for high voltages has been still further perfected and is now recognized as a properly designed and absolutely reliable terminal. Formerly one of the most difficult problems of high-voltage transformer design was to get a satisfactory outlet terminal, but now, with the condenser type it is no more difficult to design a terminal for 500 000 volts than for 100 000 volts. These terminals are made just as easily for outdoor as for indoor service. They are now being used very extensively on circuit breakers and wherever high-voltage outlet terminals are required.

Among distributing transformers many improvements have been made in details of design and methods of manufacture. These improvements, taken collectively, have resulted in greater reliability and better performance for a line of transformers that already rank high in these respects. Reliability is absolutely

necessary and good performance is an essential part of satisfactory service. Distributing transformers nearly always have their primaries connected to live circuits 24 hours a day, so that iron loss is the most important factor in determining the all-day efficiency. Every effort has been made to improve the performance in this respect with the result that the iron loss has recently been reduced considerably below the previous low values.

More attention is now paid to the accuracy of instrument transformers than ever before. A high degree of accuracy is necessary for good measuring instruments and careful attention to the design of transformers to go with them is necessary in order to secure this result. Among the difficult measurements to be made are those of ratio and phase displacement of current transformers. A new type of apparatus has just been devised by means of which these measurements can be made in a most accurate and satisfactory manner, thus assisting greatly in securing the desired results.

Experimental and research work have been carried on continuously and many of the improvements made have been brought about through these means.

PROGRESS IN THE SMALL MOTOR FIELD

BERNARD LESTER

THE popularity of small motors and small motor-driven machines continues to increase as their merits become more widely known, and the circuits of central power stations become extended into a greater proportion of the homes.

The past year has seen a large increase in the number of devices for which motors may be used. When the small motor first came into use, it was applied principally to those devices which depended entirely on it for their success, such as the portable vacuum cleaner, or the graphophone. Although the demand for motors in these fields continues, the increase in demand during the past year has been more in connection with machines which formerly were hand driven, but now are being driven by motors. Development in this direction is naturally secondary to the exploitation of a device which is useful, yet depends entirely for its utility upon the fact that it is driven by a small motor. An illustration of this is the increased de-

mand which exists for motor-driven washing machines. The washing machine is one of the oldest machines of the modern household, yet the labor in connection with it has never been in its favor. As a motor-driven device its merits are particularly pronounced, since the total amount of labor required for operating a hand-driven machine is very greatly reduced by employing an electric motor.

Aside from this the past year has also been marked by the closer analysis of small motor applications which is being made. Until very recently the attitude which has been taken by many manufacturers and large users is that the question of small motor application was mainly one of "cut and try," and not one of engineering analysis. There is duplicated in the small motor field all the problems of application encountered in the industrial field in connection with larger motors. The apparent insignificance of the individual power unit has misguided many with the idea that the field for the small motor and the problems involved in its application are also small.

The application problems always involve three parties, the motor manufacturer, the manufacturer of the driven machine, and the central station or power seller. The year of 1911 has brought greater coöperation between these three influences with the result that the public to-day can purchase small motor-driven machines designed for service conditions.

IMPROVEMENTS IN DETAIL APPARATUS

T. S. PERKINS

IN detail apparatus the tendency during 1911 has been to bring existing lines of apparatus to a higher degree of perfection rather than towards radically new developments. Considerable attention has been given to the physical proportions of some of these devices in order to make them lighter and smaller. This is particularly true of measuring instruments and fan motors.

In measuring instruments some new lines, both alternating and direct current have been developed. Particularly noticeable among these are the lines of long scale seven-inch instruments. In these instruments the reduction in size has been made without any sacrifice whatever in performance. It is obvious that this gives a material advantage in applying these instruments to

switchboards, on account of the economy in space thus secured. There has been further perfection of portable instruments which make them more accurate, permanent and rugged. Particular attention has been paid to accessibility of parts so that, in case of accident, they can be repaired in the minimum of time and at small expense.

The watthour meter development for the year has, in view of the insistent demand of the operating companies for a cheaper meter, resulted in placing on the market by all of the meter manufacturing companies of new meters embodying the same principles as existing apparatus, but worked out to permit lower manufacturing costs and hence selling price. This development has made possible the early adoption of bottom terminal meters and more legible dials. Arrangements are on foot for a revision of the Meter Code as adopted by the National Electric Light Association and the Edison Association. Several states have adopted public service laws, creating commissions with duties similar to existing public service commissions.

In lightning arrester work, perfecting of the existing types of apparatus has been continued and the development of a considerable additional number of forms and sizes. Nothing fundamentally new has been brought out, but the experimental stage of the aluminum or electrolytic type of arrester has passed, and the apparatus has been accepted as standard. The standards of insulation of apparatus in general have become such that this fact, combined with the highly effective protective apparatus, has reduced lightning trouble to comparatively harmless proportions.

The demands for control apparatus have proven that operating men are giving more attention to this class of apparatus. This is manifested by the more exacting specifications and the insistence on specialized types. The call for automatic and semi-automatic control has increased and with it the demand that greater speed and efficiency be obtained. Operating conditions have received more careful study and analysis and the ability to anticipate demands thereby gained has been of influence in extending the use of electrical drive in many industries and in opening up new fields for this power, as, for example, in oil well drilling. Remote control apparatus is gaining in favor and protective devices of all kinds are being more largely introduced.

In electric lighting, especially street lighting, there has been a noticeable increase in the use of tungsten incandescent lamps. The tungsten lamp is used in places where units of comparatively low intensity are required, and in such places arc lamps have been superseded largely by tungsten lamps. There has been a continued tendency toward a higher standard of street illumination. The year has seen the introduction in this country of the long burning flaming carbon arc lamp. It would appear that this lamp will have a very considerable application, especially where units of very high intensity are wanted.

The growth of the fan motor business has rapidly increased and the development of the year has been such as to still further extend its distribution and increase its popularity. Careful attention to design has resulted in an improvement in appearance, a reduction in weight and an increased economy of operation. Marked improvement has also been made in the oscillating fans of the mechanical operating type, both in appearance and in performance.

The field for electric cooking and heating apparatus continues to broaden in scope. There has been a material increase in the application of electric heating to different types of household devices. A device can now be found for practically every cooking operation requiring the application of heat. In industrial work there have been many new applications. These vary all the way from the small smoothing iron to the large bake-oven which will hold 350 loaves of bread. Some interesting special applications have been made, a particular one being a type of hot water heater for heating greenhouses. In this hot water plant the heating elements are immersed in the water and the water circulates through the heating pipes in the usual way. Leads from the heating elements are carried to a switchboard so that an attendant may vary the temperature at will.

DEVELOPMENTS IN PROTECTIVE RELAYS

A. W. COPLEY

FOR the protection of transmission lines and apparatus and insuring continuity of service, which in many cases is of even greater importance, it is essential that, in case of a ground or short-circuit occurring at any point in a system, the section in which the fault is located be isolated from the rest of the system in the shortest possible time. In order to obtain such iso-

lation of a fault a system of relays for operating circuit-breakers is necessary, the relays being chosen and located to suit the operating conditions of any particular case. In some places overload relays are necessary, in other reverse current, and in still others combination reverse current and overload relays must be used. Moreover, the time characteristics required in the various relays cover a wide range and must be chosen with regard to the needs of the individual case. In the past year more thought has been given to the proper application of relays in large transmission systems, and development in design has been stimulated by the call for relays with time characteristics more definite and reliable than had been previously required. The time characteristic of most relays had been either a definite time limit of a certain number of seconds irrespective of the load or an inverse time limit in which the tripping time varied inversely as about the square of the current, or, as made by one manufacturer, a combination of these two. The first gives no selective action determined by the amount of the overload; the second gives selective action under certain conditions in which the overload is less than about three or four hundred percent of normal. At very heavy overloads, in the neighborhood of a thousand percent, the selective action is not very reliable on account of the very short time element obtainable at such loads without excessive time adjustment at more moderate overloads. The third, while retaining the inverse time element, provides greater retarding action on excessive overloads than is obtainable with a simple inverse time element. The past year has seen relays developed which give a more reliable time element varying inversely as approximately the first power of the current, and with which selective action has been rendered possible under the most trying conditions.

For reverse current work relays of much more reliable action than hitherto attained have been developd and for these and the combination overload and reverse current relays which had already been developed, there has been a greatly increased demand as they meet the very rigid requirements of the modern power system. All of the higher accuracy relays have been of the "meter type," in which the contacts are operated by a metal disc rotating by inductive action in the air-gap of an electromagnet, the rotation being opposed by a control spring and retarded by damping magnets. Such relays are easily adjusted both for current or time settings; and, since they have a minimum amount of friction in the movement, the settings can be depended upon to give reliable tripping values.

RECENT DEVELOPMENTS IN ELECTRIC HEATING

W. O. PEALE

THE past year has seen no material improvement in the resistance materials used in the various makes of electrically heated apparatus, but this is of little moment inasmuch as the methods of insulating and assembling the materials at hand have so far advanced as to practically preclude the necessity for better qualities of resistors. It has long been known that the most satisfactory form of heater is one in which the heat element is in the form of thin, flat units, which give the greatest possible area for transfer of heat to the working surface and which can readily be insulated and assembled in such a manner as to protect the element from oxidizing influences and at the same time permit of the rapid and constant transfer of heat to the working surface.

This construction has been successfully developed in the well-known electric irons and electric toaster stoves which have been on the market for several years. In the past year this principle has been successfully applied to various other devices, such as electric chafing dishes, frying pans, percolators, etc.

It is also worthy of note that more attention has been paid to the efficiency of application of the heaters to the various devices, which results in a lower operating cost than was obtained with the older methods. For instance, the use of immersion heaters wherever possible, in preference to an external stove, results in a great saving to the user, while other devices such as frying pans and chafing dishes are being made self-contained and as light as consistent with good design, which gives very quick heating with practically no loss of energy.

There have been several applications of electric heat to large hot water and steam generators. A very efficient form of heater has been developed, consisting of a copper container within which the heating element is assembled under heavy pressure. This element is immersed in the water and all of the heat supplied must pass into the liquid. The only loss is that by radiation from the external surface of the vessel or boiler.

Without going into details, it may be stated that the field of electric heating is developing and broadening very rapidly and that the past year has seen more real advancement in the practicability and usefulness of the devices marketed than any previous season.

PRIME MOVERS FOR CENTRAL STATIONS*

THEIR ECONOMIC RELATION

EDWIN D. DREYFUS

CONVERSION of the potential energy of our various commercial fuels into mechanical power is at present successfully accomplished thermodynamically through the use of the steam engine, the steam turbine, the gas engine, and in some cases where oil enters the fuel market prominently, the oil engine. Each of these classes of prime movers has reached a high crest of development,—both the steam motor, firing the fuel externally and operating through the agency of steam; and the internal combustion engine. In the latter case, the form of motive power has, in practice, been restricted to the piston engine, gas turbines having been greatly retarded by the difficulty of establishing an efficient cycle of operation and of securing materials of construction which will withstand the working temperatures and action of the gases. There have been built and operated for experimental purposes, several gas turbines, but so far they have given small promise of practical application.

Excepting, then, the gas turbine, the four heat engines above defined, may now be depended upon for reliable service, and their particular selection in any case, will be found to be governed by the nature of the demand and the surrounding conditions, such as extent of power, capacity or station factor, character of load, value of fuel, cost of labor and materials, and other operating considerations. It is not the intent of the author to espouse the cause of any one of these different types, but to review some of the elements of ultimate cost of producing mechanical energy and its conversion into electric current, which bear upon immediate and future economy.

The hydraulic turbine is only a competitor of the heat engine (in the low-priced fuel districts) where the cost of development, including the acquisition of riparian rights, is moderate, the points of consumption of the power within reasonable radii, and the probable load factor or demand sufficient to warrant the cost of dams, flumes, machinery and transmission lines.

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*Paper read before the *Association of Iron and Steel Electrical Engineers.*

Generally regarded, the different types of prime movers have specific fields wherein they have the greatest usefulness, and this condition will probably hold for an indefinite period. About the most revolutionary event which might occur in the arts, would be the evolution of an electro-chemical process of transforming the stores of energy in fuel into electric power in a single step which will comprise apparatus constituted of commercially economical materials. This obscure subject has not been neglected by the inventor, but no practical results have yet been produced. While there are systems in which electro-chemical transformation is possible, they involve the use of rare metals, and it therefore becomes of little value to the industries.

A departure of some note from the use of the chemical energy embosomed in the earth, or that of the difference in level of streams or rivers, is the contrivance of solar motor systems, directly utilizing the radiant energy of the sun. They have become *a fait accompli*, and may be operated successfully under favorable auspices. Their commercial application, owing to working conditions and high first cost, is restricted virtually to tropical regions where fuel is particularly expensive; the solar heat most constant; and consistent loads obtain, as in irrigation work, necessary for the long, dry seasons in the arid and torrid zones.

MECHANICAL STATUS

Tendencies in American practice lean decidedly toward maximum simplicity of construction which, however, is restrained to the extent of not prejudicing efficiencies. These factors contribute to economy in manufacture and low cost of operation and maintenance.

Reciprocating Steam Engines, which were the principal source of power in the latter half of the nineteenth century, have since given way to the more economical types,—the turbine and the gas engine, which became commercial products a short time before the expiration of that period. It is usually true that competition, created by a new invention, inspires or compels progress and development in the old line of apparatus, and for this reason, we are about to experience a brief renascent period of the piston steam engine through the introduction of the Stumpf and the Lentz designs. The prime object attempted is the reduction of clearance and condensation losses. The straight-flow principle of the Stumpf engine, having exhaust ports located at the center of the cylinder

and with a deep piston travelling far enough to uncover the ports at the proper points in the cycle, has much to commend it. Lentz compound engines are "short built," and consequently compact—one head only between the high and low-pressure cylinders, dispensing, therefore, with one gland. Steam passes from the high to the low-pressure cylinder in a spiral path around the outer walls, which is presumed to minimize the condensation losses. Reducing clearances by oblique poppet valves located in the cylinder corners, represents the essential features of the *Memming* engine, *which is also a recent development*. These engines have been used extensively abroad, but in this country are at present limited to one or two installations. The advent of these improvements may produce a renewed lease of life, where this type of prime mover favorably holds ground; but the already permanent invasion of the steam turbine, accelerated by its important economies in investment and operation, will prevent a general use of this improved type of reciprocating engine. A review of the details of these engines will in general reveal features which the American engineer has shown a disposition to avoid. The Stumpf engine, owing to the length of piston and high initial stresses, must employ heavy reciprocating parts, which, at their rated speed, exact expensive foundations, and obviously a good or else reinforced bearing soil, or rock. Lentz engines are in many parts difficult of access, embody elaborate gear, and also have heavy reciprocating parts; and the Memming type is so unusual with its oblique valves, that it necessitates no special comment. For locomotive cylinders, they bid fair, *however*, to introduce a better era, and this may apply to certain classes of mill work where the piston type engine is used.

A composite steam power equipment has appeared within the last few years in the *Locomobile* type of construction, conjoining boiler, engine and condenser into an assembled whole. In this way the high-pressure cylinder is located in the smoke flue and the jacket of the low-pressure cylinder establishes the steam dome for the boiler, which, together with the use of high superheats and internal furnace, conduces toward very good economics. It is reported that a brake-horse-power has been developed on about one pound of coal, paralleling gas-engine performance. Here we have another example of certain European practice, once more leading in the use of very special machinery, inspired, evidently, by conditions peculiar to their country. It remains, as yet, an open question if such appar-

atus will be extensively used in America, its seeming efficiency notwithstanding, for the reason that its unusual construction must be attended by a high order of skilled operatives so that heavy repair expense may be averted. By the nature of its construction it should be limited as a probability to 600 horse-power as the maximum capacity of a single unit. It is rather extraordinary that sizes larger than this should be built.

Steam Turbine Work, abroad as well as in this country, has been principally characterized by the policy of departing from fixed lines of design and introducing into the turbine the action and reaction principles, either combined or separately employed, as costs and operating factors may dictate. Briefly, the result has been that small turbines are made with the simple impulse wheel, moderate capacities use reaction blading, and large units embody both impulse and Parsons sections. With greater experience and familiarity with turbines, the reasons for the distinct uses of the different methods of construction are constantly becoming more evident, being a very natural evolution. The application of the steam turbine to various services has become very marked during the past few years, it is at present being successfully used in connection with a reduction gear with direct-current generators, for centrifugal pump drive, and also for rolling mill work. Marine engineering has always been an exceptionally favorable field for the turbine, and its development for this service has been aided in no small degree by the introduction of the large reduction gear. One of the most striking points of the steam turbine has been its easy adaptation to so wide a range of capacities for practical purposes, extending from sizes of less than one kilowatt to the powerful unit of 30 000 kilowatts. And it is with ample justification that authorities on the subject prophesy that single turbines of 50 000 kilowatts will soon reach a point of realization.

Again, the turbine has proven itself a worthy adjunct to preceding *types* of equipment, principally the steam engine, through its ability to work economically in low pressure ranges entirely; and this same qualification may open up an important field for the turbine as an auxiliary to the gas engine plant in the utilization of waste heat. While installations of this *latter* character have been contemplated in this country, it is only in Europe that they have been put to a practical test. In thus combining the turbine and *gas* engine systems, there are attractive opportunities for saving from six to twelve percent in the investment, and from six to fifteen percent

in operating expense. Although the installation of the low pressure turbine would be added to the more intricate gas engine layout, it would not introduce complications, or a complexity, as some may aver. In a properly designed plant each of these component parts would be independent of the other, but at the same time interrelated; and if so dissociated in mind, the simplicity of operation to be gained by means of the waste heat turbine will be plainly evident. In fact such measures must be resorted to in order to make the position of the gas engine tenable where widely swinging loads are encountered. Those experienced in the operation and maintenance of the lead storage batteries, alone, will perceive the real importance of such a "thermo-mechanical" system of storage and transformation in which may be observed, as correlaries—

1—Marked simplicity of detail.

2—Conservation of waste heat energy.

3—Improved operation and economy of main equipment.

4—Interruption of service precluded (in its implied sense).

Analogous to that resulting from the use of the lead storage battery.

5—Exempt from disadvantages peculiar to the battery system; viz.—

a—Deterioration of lead plates.

b—Loss of energy in charging and discharging.

6—Low initial and operating cost, compared with the expense of the lead battery.

7—Absence of booster set for direct-current, or rotary converter for alternating-current work required by the electric storage battery.*

It is, therefore, not without cogent reasons that the character of installation is presaged to early assume a prominent part in connection with gas power development.

Combined steam engine-turbine equipment for new stations, however, would produce no material advance over the straight turbine installation due to the great saving of the latter type in investment, oil, labor, and maintenance.

The turbine has also become in a very notable way, a part af the power house auxiliary equipment, furnishing power for the condenser, and the boiler feed and excitation systems.

*It is to be noted that the low-pressure turbine is not simply an "in stromitary" like the booster or rotary converter, but is distinctly a prime mover in itself, which at the same time allows of regulation to supply peak demands precisely as occurs in floating the battery on the line.

Gas Engines have gained most prominence through their use in the iron and steel mills. Blast furnace gas power plants have of course, been more striking, owing to their magnitude. It is patent that the development of the gas engine has been attended with relatively greater troubles than most other types of prime movers, but the difficulties met with were in no wise insuperable as the status of blast furnace and natural gas power operation exhibits. The growing satisfaction with the service of the gas engine may be attributed, in part, to reinforcement of cylinder castings, simplification of cylinder, piston, and rod construction, better packing design and the general adoption of throttling governors. Despite early experiences, the gas engine built and installed with proper provision for the service, should now be found virtually as dependable as other power machinery. Considering diversity of service, the gas engine is apparently more restricted in its use, and is also fairly limited as to the power which may be produced in a single unit. In consequence, there has developed on the part of some manufacturers, a disposition to increase speeds. This step should be taken slowly and deliberately so as not to remove the conservatism so essential to permanency of results. High speeds have been used in steam engine practice, but this fact should not be employed as a criterion in gas engine work wherein the operating factors are so different and the weight of parts and maximum pressures and temperatures within the cylinder are so far in excess.

While gas engines of the twin tandem type may be provided in capacities as high as 5 000 brake-horse-power, little, if any, demand will arise for units of these proportions, especially in this country. The future may develop some improvements which will ameliorate the economic disadvantages of the high power gas engines.

Oil Engines have progressed slowly in this country, while abroad they appear to be viewed with high favor in some districts. The thermal economy of the oil engine has been manifest, but, up to the present time, the excessive repair occasioned by the cylinders, valves, piston rings, etc., has had a great baneful effect, and consequently dwarfed the development of the oil engine. Many revisions in design have been brought about lately, and it is probable that this will, to some considerable extent revive the trade. Similar to gas engines, however, the oil engine is restricted in size and will be confined to stations of moderate or small capacity, although in Germany oil en-

gines of 2 500 brake-horse-power now exist. Inasmuch as the oil engine prepares the fuel in itself for combustion, (without intermediate steps,) it establishes a unique type of emergency equipment in case of the failure of the regular power supply obtained from other sources. In some cases, on the other hand, it may be considered more unique than important, depending of course upon local conditions and the economic factors which may obtain.

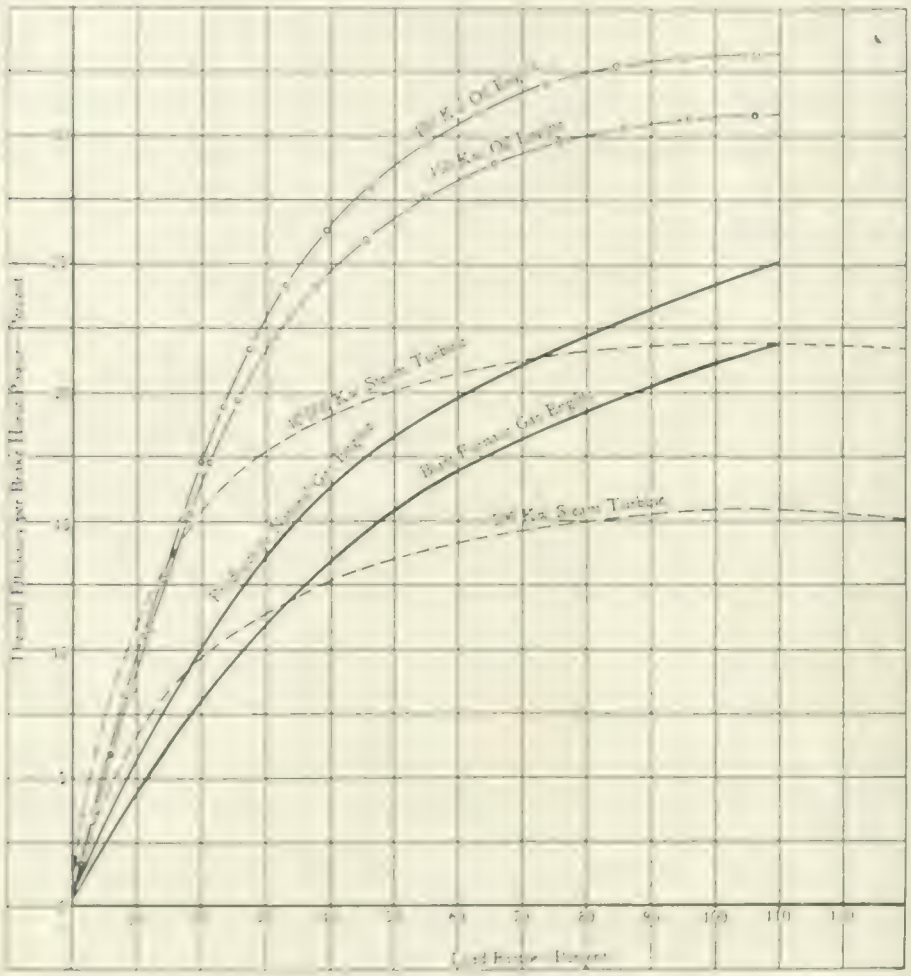


FIG. 1—OVERALL THERMAL EFFICIENCIES OF MAIN UNITS
Based on total heat values per brake horse-power. No allowance for auxiliaries.

EFFICIENCY OF MAIN UNITS

The superior efficiency of the internal combustion engine is so evident in certain ranges, that a statement of such facts seems commonplace and hackneyed. But regarding this important relationship in the abstract may cause momentous and lamentable blunders. An effort will, therefore, be made to illustrate wherein this general conception is susceptible to illusion.

Oil engines lead with an efficiency of 30 to 33 percent (full load)

referred to the shaft horse-power. Gas engines ordinarily show about 23 to 26 percent heat efficiency on the same basis. Steam piston engines and turbines have a wide range of thermal efficiency, from 5 percent or less, to as high as 21 percent on brake-horse-power test. Both steam motor and gas engine efficiencies are reckoned on the heat in the steam or gas delivered to the throttle valve, and include no losses due to the boiler and the producer or cleaning apparatus where these are used. The gas engine remains more uniform in efficiency over its range of sizes than other types, and may be fairly represented by a typical efficiency curve, Fig. 1.

Oil engine economies vary in a small degree with capacity, while the steam motor is subject to wide flunctuations. The oil engine percentages previously given, apply to normal rated capacity, and it is important to observe that the fractional load consumptions are in no wise proportionate, and as shown in Fig. 1, may reverse their relative value from the fuel standpoint. Lack of knowledge, or failure to heed these facts and other modifying conditions, have proved to be responsible for the "misfit" of some of these types of power machinery for circumscribed requirements—plainly retrogression in our economic affairs.

It is also incumbent upon the engineer to contemplate another condition of operation; viz., decline in efficiency through service. Changes naturally take place in all types, but are more marked in some than in others. Piston type engines with corresponding duplicate admission and exhaust valves, evidently experience the greatest losses from wear and inadjustment. Stumpf engines are designed to partially *mitigate* these conditions. Turbines, in which rubbing surfaces and tight valve seats do not enter the economy question, are manifestly subject to the least deterioration. It is not to be implied that in every case the turbine has been immune from depreciation in use, for this has occurred in some constructions due to faulty materials and design; and again, the blades and walls of the turbine have been seriously affected as a result of the quality and chemical properties of the steam. However, in some of the most prominent examples, practically two, of erosive and corrosive action, the efficiency of the turbine decreased but seven to ten percent. One test of a large turbine which had developed moderate wall erosion, proved that the machine had not fallen off in efficiency with the clearances slightly increased over the ends of the rotating blades, it being properly contended that a free passage was thus provided for the flow of entrained moisture with the least

hydraulic friction. Steam turbines do not need so constant attention in order to maintain a good state of repair and efficiency; and inasmuch as no appreciable wear has been reported in the majority of turbine plants, this type of engine should be charged with but a small "loss-factor", if any. While the efficiency of the piston type may be sustained only within three percent of its original economy, it is more likely to suffer impairment of 10 to 25 percent, according to the care exercised in operation and upkeep.

COMPLEMENTAL AND AUXILIARY EQUIPMENT

In every high pressure steam plant, steam generators must, of course, be provided. There are many low pressure turbine power plants, however, where boilers are unnecessary for power purposes; but these, of course, come within the domain of special applications. Oil engine plants,—with the exception of the starting, pumping and excitation apparatus, are virtually self-contained. The gas engine supply is obtained either by the conversion of coal, wood, oil, or kindred fuels, into a gaseous product in a producer; or on the other hand, from natural resources, or the recovery of waste or by-product gases from blast furnaces and coke ovens. These have enabled a wide application of the gas engine, amounting to over 75 percent of the total gas power machinery installed. This outcome is entirely logical, since in the latter case conversion losses of 25 to 35 percent are obviated. On this vantage-ground, larger gas engine installations have been justified than in cases where producer losses appear.

Boiler efficiency is a variable quantity, depending upon the fuel, the construction of the furnace and grates, or tuyeres, and the attendance and supervision. As high as 80 percent efficiency or slightly above may be obtained under test with a gaseous or liquid fuel, but in regular operation much lower efficiencies obtain with these same fuels, 60 to 75 percent, hinging upon cleanliness of the fuel (blast furnace gas, for example) delivered to the boiler. Coal-fired boiler plants do not perform quite so well, ranging from about 76 percent as their highest efficiency ordinarily (barring exceptional tests), in the modern metropolitan plants, to 50 percent in the smaller isolated stations. Fortunately both boilers and producers hold up fairly well on light loads—in either case, within about ten percent of the efficiency at rated capacity when operating on quarter-load.

If the plant does not operate continuously at full capacity, part of the equipment is cut out of service during certain hours of the day, and the fires must be kept in condition for quickly responding

to the demands for steam or gas. Thus in all plants burning or gasifying coal, a certain *standby loss* is experienced, and where equal skill in plant operation obtains, the amounts in each type of plant compare favorably. The power required to operate the auxiliary apparatus must be deducted next from the combined efficiency of the engines and boilers and producers. In the gas and oil engine plants, the auxiliary heat consumption is not subject to much variation, whether electric motor or engine drive is used, and a typical percentage is 7.5 percent of the main unit full-load value, or quantity, which holds quite uniform over all ranges of load under ordinary conditions of operation, and for large and small plants as well. Oil engine auxiliaries consume, roughly, 15 percent of the normal load requirement, of which ten percent is demanded by the air compressor. As there is more latitude possible in choosing steam plant auxiliaries, there will consequently be found a wide difference in economy realized by this part of the station equipment. Where the engineer is successful in striking off a good heat balance, having all auxiliary exhaust returned to the boiler feed system through the feed water heater and the feed temperature above 200 deg. F., the increased draft on the coal pile produced by the auxiliaries should not, in the small plant exceed eight percent and in the large plant five percent. But careless designing and operation may easily cause these percentages to be doubled. The relative requirements of the auxiliaries in steam plants increase less rapidly than in other types.

There is, of course, a small allowance for radiation to be included in the consumption of the steam plant which where the piping and radiating surfaces are sufficiently protected with nonconducting lagging, is safely covered by the addition of one percent. In the case of natural, or by-product gases, many of the losses expressed above, are of course, absent.

The high-speed turbo-generator possesses lower mechanical efficiencies on account of greater windage losses, but less excitation current is demanded, so that the electrical considerations have only a light bearing upon the comparison.

DISCREPANCY AND DEFICIENCY LOSSES

No system of machinery can hope to escape some inevitable losses which do not readily lend themselves to mathematical calculation; and, therefore, the introduction of a small discrepancy factor becomes expedient, subject, however, to discretional analysis and the judgment of experience. This division, therefore, takes care

of losses not directly accounted for, such as the blowing down of the boilers, popping off steam, cleaning fires, leakages, etc., in the steam plant; purging of producer, leakage of gas, misfiring, etc., in the gas plant; and appreciable fuel leakage in the oil engine system. Moreover, there are also losses through impairment of efficiency to be considered. These are due to soot deposits on tubes, air infiltration through cracked settings and improperly ventilated fires of the boiler, clinkering and channeling of fires in the producer, and

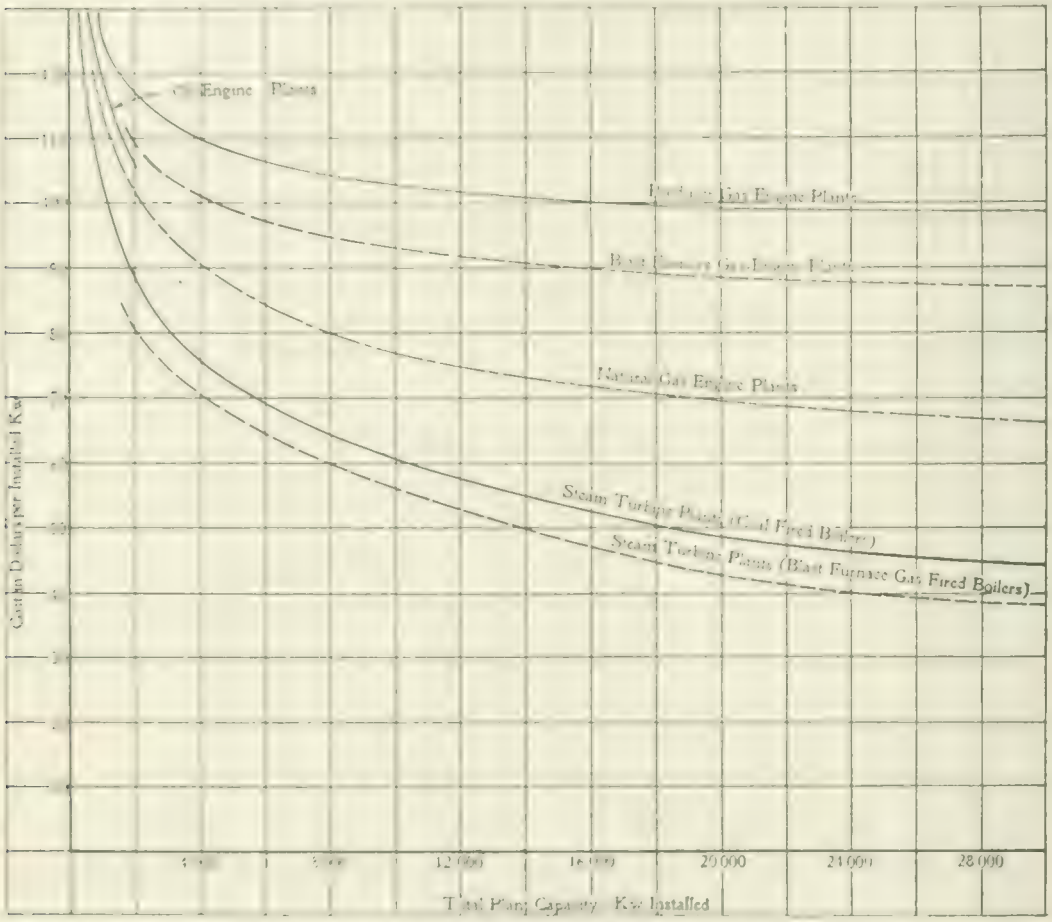


FIG. 2—PLANT INSTALLMENT COSTS
Normal rated units, including buildings and foundations.

poor fuel regulation in oil engines. In the steam, gas, and oil plants, they may be empirically expressed in the ratio of 5, 2, and 1, respectively, for full-load condition, and manifestly become more preponderant on reduced outputs.

These features of power plant operation plainly indicate one of the most important duties of the management, to prevent excessive losses through such causes; and a rigid policy should be enforced to minimize these losses which, if not guarded, may result in most unsatisfactory economies.

COST OF INSTALLATIONS

Through constructional requirements, the type which is inherently the most efficient becomes the most costly to build and install. This state evidently adds further complexity to the problem, but which may be solved by extended investigation.

The total cost of the different types of power plants may be affected by many considerations, such as the individual character of plant design; the efficiency of construction; the quality of materials and equipment; the degree of conservatism, and the effect of location on the installation expense. Thus the personal quality and locality largely influence the unit cost of the undertaking, and consequently there can be no other result than a considerable disparity between the aggregate investment of stations of like capacity laid down under different management and supervision. With full knowledge of these facts, the author shows in Fig. 2 some proportionate curves which, in the main, may be viewed as representative costs per unit of capacity of the three leading types of installations *based on normal ratings,* and which include every item of expense entailed in preparing the plants for regular service.

A characteristic feature of the gas plant is that the unit cost steadily decreases until two, or more, 2 000 kilowatt units are reached, when the investment then increases directly with the capacity installed. But with the steam turbine station, the kilowatt or horsepower cost constantly diminishes with size.

It will, therefore, be seen that the ratio of cost of steam and gas stations constantly grows in favor of the former, so that gas power becomes severely handicapped in large work owing to the proportionately greater investment burden. And unless fuel prices rise materially above their present value by virtue of exhaustion of fuel sources, or conservation, the gas engine finds limited application in the large station class, except under favorable circumstances where the fuel exists in a *natural* gaseous state or as a by-product gas.

Many improvements have been made in power station apparatus with the last few years, establishing substantial reduction in cost. In most cases it may be stated that with the present build of machinery, the situation has now about reached the low level. With the increasing competition which has lately presented itself in the oil engine market, the cost of this class of product will undoubtedly be much reformed.

The disadvantage of high first-cost has induced an effort to in-

crease the speed ratings of the gas engine, thereby obtaining higher power without greater cost, or the same capacity with a design less expensive to manufacture. Any improved practice which finally realizes an economic gain is, of course, an advantage to the art, but one should act guardedly in the effort to secure low cost of producing power in order not to introduce operating ills by overreaching our purpose. It is true that single acting-engines have worked very successfully at high speeds with connecting rods fairly loose on the pins owing to the pressure being exerted in but one direction. A double-acting engine, however, precludes similar high speeds, as rotative speeds are soon reached where the jar due to unavoidable clearances, and especially with the heavy masses involved in the reciprocating parts of the gas engine, would become destructive, entailing not necessarily immediate disaster, but high maintenance cost.

OVERLOAD CAPACITY AND RESERVE UNITS

Comparative station cost is subject to another factor which may easily reverse the relative advantages of the types, and which bears upon the intrinsic character of the load and the quality of service to be supplied. The simplest case is where the power demand is altogether steady, or as may be said, where an absolutely flat load curve obtains, and the losses in event of enforced shut-down are of no great moment. Contrarily, if the interruption of power endangers the operation of some industry, causes serious tie-ups, or creates public or private inconvenience or other embarrassment to service, adequate spare equipment must be provided to ensure continuity of service. This reserve proves a costly premium in case of expensive apparatus, and naturally suggests the combination of different types in important stations.

Widely swinging load works a hardship to the gas engine, as this condition mitigates against its highest efficiency which must be sacrificed, and the engine operated at a low loading due to its limited overload capacity. On the other hand, the steam turbine can develop generous over-loads, and, therefore, may normally be worked at its most economical rating.

Again, the disadvantage of small marginal over-loads will be felt by the gas engine where the load is characterized by peaks occurring at different periods of the day. The losses to be endured by a plant equipped entirely with gas engines, due to cutting in and out of units to accommodate the load, will be considerable in order to avoid dangerous overloading. These considerations raise the ratio of cost of the steam and gas types over that shown in Fig. 2.

LOAD FACTOR AND STATION FACTOR

Misleading ideas are frequently obtained by confusion of what is known as "load factor" and what may be termed the "station factor." What is meant in the first case, is the ratio of the average load to the maximum demand, and in the second, the ratio of average load to total station capacity which, in referring to the ultimate cost of generation, embraces the investment. It might be reasoned that the first designation would be the more fitting to employ generally, and it does serve sufficiently where operating expense only is concerned. For gauging total cost, it is believed that station factor is the preferable expression; but, in any case, the plant description should include all consideration which had had an influence on the extent of investment.

The effect of different degrees of loading on the plant has for some time been so well covered, that the majority of those engaged in power business, or users of power, recognize the value of high load factors. The discussion of this subject has been confined mostly to a single system, with exceptions, of course, as in papers by Mr. H. G. Stott and other leading engineers. It is believed that this phase of the subject is worthy of special emphasis, particularly in the comparison of different types of equipment, and the author, therefore, presents a family of equality curves in Fig. 3, which best illuminates the effect of different station or capacity factors. These curves essentially obtain for specific conditions, and from the aforegoing, would obviously be modified by different working and labor conditions, cost and interest charges. It points very clearly to the limiting boundary of the present gas engine field with existing fuel values, and likewise that of the oil engine, even with the assumed conditions favoring the gas and oil equipments.

Many may have wondered why the internal combustion engine did not become more popular in the large station, and here is the answer. In some cases, as has been stated, it has been found more fashionable than economical. It is to be remembered that these remarks apply only to large capacities, and low fuel prices. When the conditions change, the utility of the gas plant assumes a different and more important aspect.

FUEL SUPPLY

From what has preceded, it is plaintly evident that the fuel item is a significant factor, and as it is variable throughout the country, each section suggests the adoption of the type of power plant best suited to its conditions. The study of the relationship

of gas, steam and oil power, develops the fact that a change in basic conditions may easily "turn the tide" in favor of one type or the other.

Coal prices are steadily advancing. The average prices at the mines in the United States, proportioned according to the relative quantities of Anthracite and Bituminious grades mined, were in—

1898	$0.92	"Coal Statistics," Pub. by Alder & Ruley.
1901	1.22	
1903	1.31*	
1905	1.31	Similarly proportioned from U. S. Gov. Geol. Survey Report, 1909.
1908	1.30	

Manifestly these tabulations are proportional and not an absolute measure of their periodic values.

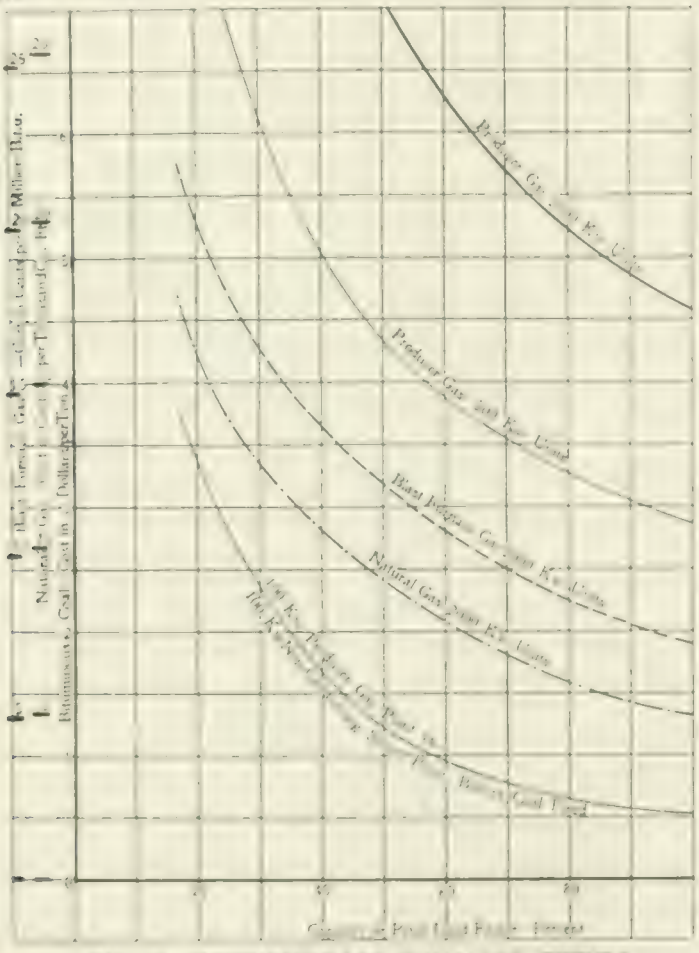


FIG. 2—PROPORTIONATE EQUALITY CURVES

Showing balance of total costs of generation in gas and steam plants with variable fuel prices and load factors.

Territory above curves favors the gas engine; below, the steam turbine plants prove more economical. Based on general conditions in the text.

Fuel values:—

Bituminous coal	13 000 b.t.u.
Natural gas	975 b.t.u.
Blast furnace gas	80 b.t.u.

*Influenced by the general strike of 1903.

The policy of conservation may, in the early future, be felt in the coal market, and, with the annual tonnage under regulation, there will be a further tendency toward a rise in prices.

Oil is now being produced in large quantities, principally in the Southwest. This, of course, creates a cheap fuel for the oil engine, but there remains some question as to the stability of these low prices when we consider the many valuable uses to which this mineral may be applied, such as heating furnaces (owing to the high temperatures attainable), and generally, for industrial, chemical and medicinal purposes.

By-product gases are least affected by market conditions; however, they are frequently valued accordingly. The natural gas sources being limited, will tend to raise the cost of this fuel.

LABOR ELEMENT

Wages become from 19 to 13 percent of the total power plant charge in the steam plant, and from 23 to 20 percent in the gas producer plant when considering the charges at 50 percent plant load factor, with fuel at $2.50 per ton. Gas plants without producers, and the oil engine, consume about 20 to 13 percent of the total expense for labor under the same conditions. These percentages obviously bear no relation to one another, as they are based on different total quantities. But, in general, the labor cost in the producer plant is one and one-half to two times that of a steam station, depending upon the size and number of units installed. Where producers are not required, the labor is practically equal, and, in small one-unit plants, may be less.

The apportionment of labor and wages in both steam and internal combustion engine plants, must be undertaken with a broad and liberal view to properly keep up the plant, thus safeguarding the reliability and continuity of service. It may be well to observe that, although it is more often the case that a greater number of men are employed than is necessary to obtain these results, it is not unusual that the management, in its endeavor to cut the expense to the lowest attainable point in the matter of labor, do so to the detriment of the service and the life of the machinery, and in making comparison, it should properly be determined by such a course.

One of the chief elements entering into the labor charge of a plant, is the length of the shifts on which the men work. For small plants, the shorter shift is evidently not expedient as the men have less to do and have less responsibility. The labor costs in small

plants are a more important factor, and to change the force from two to three shifts, means an addition of 50 percent to the labor charge, which no small plant could afford. With larger plants of 4 000 kilowatt capacity and above, the labor charge is not as large as compared with the total operating charge, and since a large number of men are employed, their duties can be more definite, giving them as much or more work to do in eight hours as a man would be required to do in a small plant in twelve hours. If they are called upon to do this work for twelve hours, it will soon be found that it will not be done, and therefore it becomes a question of either employing more men on twelve-hour shifts or a change to an eight-hour shift. There are many advantage in the shorter shift, such as better satisfied men, and, consequently, more conscientious work and a better maintained plant. Also the men are available for overtime work in case of an emergency.

Owing to its greater size, more complex system, larger number of parts with unavoidable wear and readjustment necessary, the gas and oil engine plants require a larger labor force than does the turbine. For these reasons the salaries of the chief engineer and his assistants should be slightly higher in gas or oil plants than for the steam turbine. Otherwise the rate of pay should correspond.

The compensation of the working class has been steadily increasing as the following tabulation of average wages paid unskilled labor, proves.

1860	(assumed unity)	1.00	*
1870	.....	1.83	*
1880	.....	1.27	*
1890	.....	1.42	*
1900	.....	1.75	†
1910	.....	2.00	†

The disproportionate wages paid labor in 1870 was occasioned by an increase in one branch of labor which was not only exceptional from the advance in pay, but also from the percentage of men engaged. Mechanics and operators have, it is understood, received corresponding, or possibly greater increments of wages. These abstract facts indicate that there is a small rise in labor with time, and such statements regarding the labor and fuel situation are made merely that it may *assist not only in adopting the different*

*Wages of Unskilled Labor, by Edith Abbott, *Journal of Political Economy*, Vol. XIII, No. 3.

†Pay roll statistics furnished by W. J Boston.

types of equipment to our present needs, but moreover *ensure its material economy* throughout its period of useful life.

OIL, WASTE AND MISCELLANEOUS SUPPLIES

The expense occurring under this classification under normal conditions, appears as a small portion of the whole, say two to six percent. It is fitting and necessary in any comparison or estimate, to calculate their sum. The author, fortunately for the sake of simplicity, has found that it works out to be 20 percent of the labor charge *in the plant of two or more units.* There are naturally some very wide variations (10 to 60 percent) obtaining in special cases, due to peculiar local or personal factors *and the quality of these stores;* and this will be particularly true in a one unit turbine plant where economy in labor cannot well be secured and this item may become ten percent or less of the labor charge. But the value of 20 percent of the labor, as referred to, serves very satisfactorily as an average. Good water, if not abundant, increases this account, and any expense necessitated should be included.

REPAIRS AND MAINTENANCE

The charge for repairs and maintenance may become quite variable, and is as much a subject of good and efficient management in maintaining the equipment, as a question of high grade apparatus. The character of the working, and also the age of the plant have a dual bearing on operation. The repair costs of a number of turbine and gas engine plants were investigated as far as possible, and a large element of judgment had to be applied to give proper weight to the different reports, to allow for the peculiar local conditions, the personal equation and material efficiency. The repair and maintenance charges from a series of analyses of actual reports, seem to justify the following arbitrary rates:—

Turbine Systems—1.75 percent at 100 percent load factor, to 1.37 at 25 percent load factor, of the original cost of the complete plant.

Gas and Oil Engine Systems—2.25 percent, at 100 percent load factor to 1.8 percent, at 25 percent load factor, of the original cost of the complete plant.

Since the gas engine costs so much more than the turbine in the first place, this charge is evidently much greater for the gas engine than these percentages indicate.

PROFITS AND PROTECTION OF INVESTED MONEY

Every power plant installation should be carefully scrutinized as to its interest earning capacity, even though it may only be sup-

plementary to some important manufactory or industry. Obviously the solvency and prosperity of the public utility company centers about its generating station. The underlying thought, then, is that all factors which secure and make the investment profitable at all periods of its life, should be judiciously regarded. These embrace extraneous costs in development, interest, sinking fund for depreciation and supercession, administration and legal expense.

CONCLUSIONS

It has only been possible in this paper to differentiate the elements of these subjects in a very general way. There is, notwithstanding, a need for broadly summarizing the power situation owing to the uncertainty of the fields of greatest usefulness of the different designs of power machinery. The suggestion is also proffered that the engineer enter the problems searchingly from every angle, mechanically and commercially. And, moreover, where the primary loading is low, to institute campaigns for, or urge the sale of power for uses which would work in well with the original demand, such as electrical fixation of nitrogen, electrical steel refining, aluminum reduction, manufacture of caustic soda and chlorine, electrolytic bleaching, and pumping and sterilization of water. If located favorably, copper refining, irrigation and reclamation pumping may be supplied. In strictly public utility service, railway, lighting and ice plants, the loads continue when depression may be experienced in the industrial market. The filling up of gaps or valleys in the load curve is the slogan of every central station manager.

Then, in a general way, it may be concluded that in small capacities with high coal cost and no other requirement than power, the gas engine should ordinarily prevail, the oil engine sharing where the price of oil may introduce this competition. Large stations should contain steam equipment unless there be fortuitous conditions, as available gas and a small number of units which may rule differently.

IMPROVEMENTS IN MARINE TURBINE REDUCTION GEAR

H. E. LONGWELL

UNTIL recently, there have been but few attempts to construct gearing for the transmission of large powers at unusually high tooth speeds. The importance of a system of noiseless gearing to be interposed between a high speed turbine and the screw shaft of a vessel involving the transmission of many thousands of horse-power, has made the attainment of this object an exceedingly attractive field of investigation. The most serious problem confronting the designer of such a system of gearing has been the development of a mechanism to insure an elastic, uniformly distributed tooth pressure between gear and pinion, to avoid the concentration of an excessive tooth pressure at any single point of the working face, which would result in rapid deterioration and ultimate destruction of the teeth. This problem—which is by no means an easy one—has been effectively and interestingly solved in the Westinghouse marine turbine reduction gear.

A perspective view, partly in section, of one of the gears installed on the U. S. S. "Neptune," is shown in Fig. 1. Each gear transmits approximately 4000 horse-power at a speed of 1250 r. p. m. for the pinion shaft, and about 130 r. p. m. for the low-speed or driven shaft. Naturally, double helical gears are used on account of the quiet running qualities of this type, and the fact that the opposing helices automatically balance the end thrust. The low-speed gear shaft rests in bearings seated in the main casing, and up to this point the design is fairly conventional.

The essential and distinctively novel feature of this design is the hydraulically supported frame which carries the pinion shaft and its bearings, and by virtue of which the pinion shaft is self-aligning, responding instantly to the smallest unbalancing of the tooth pressure. This method of suspending the pinion bearing frame not only insures the most perfect balancing of tooth pressures, but the fluid cushion interposed between the pinion shaft and the main casing of the gear silences in a large measure the noise usually associated with the operation of high-speed toothed gearing, and prevents all shock or jar from the rapid contacting of the teeth. After a considerable period of operation, the gear

teeth take on an excellent polish and show no signs of pitting or other deterioration that usually accompanies hard and continuous service.

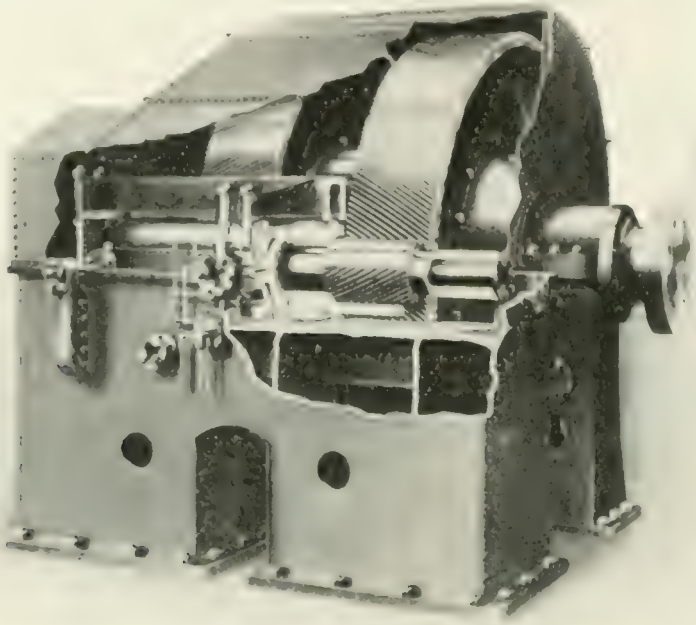


FIG. 1—PERSPECTIVE VIEW, PARTLY IN SECTION, OF MARINE REDUCTION GEAR

With supporting cylinders above and beneath pinion for reversing operation.

The action of this hydraulically supported frame may be more easily understood by first inspecting Fig. 2, which is a purely diagrammatic section stripped of all mechanical detail that might be confusing, and which illustrates the simple elemental principles of the design. Fully elaborated detail sections are shown in Figs. 3 and 4, and the symbols used in the description refer to the same

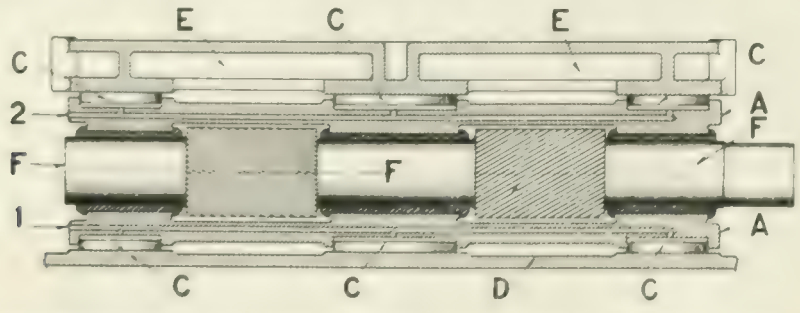


FIG. 2—DETAIL SKETCH SHOWING PRINCIPLE OF OPERATION

parts in all of the illustrations. Referring to Fig. 2, *A* represents the frame carrying the bearings of the pinion shaft, *D* is a portion of the main casing, and *E* is a rigid strut or beam secured to the

main casing by means of a series of steel columns. It will be noted that *A* does not fit closely between the parallel faces of *D* and *E*, but has freedom for a slight upward and downward movement. On the upper and lower surfaces of *A*, are three circular pads bored out to form shallow cylinders in which are fitted short pistons *C*. *1* indicates a passage or port, which communicates with the three shallow cylinders on the lower side of the frame *A*, and *2* indicates a similar port communicating with the corresponding cylinders on the top side of *A*.

When the gear is working, the reaction on the pinion teeth will

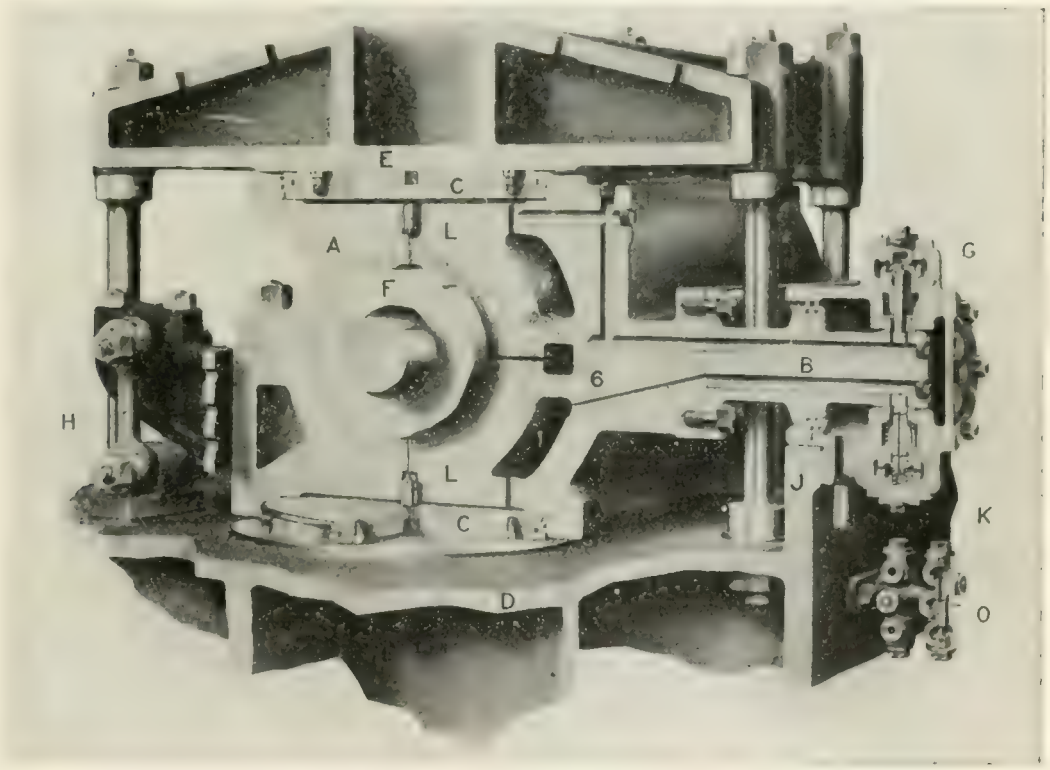


FIG. 3—SECTION THROUGH MIDDLE BEARING OF PINION, FLOATING FRAME, OPERATING ARM AND VALVES CONTROLLING OIL ADMISSION TO HYDRAULIC CYLINDERS

tend to force the frame *A* against the casing *D* or the beam *E*, depending on the direction of rotation. If the reaction on the pinion teeth tends to force the frame *A* downward against *D*, then if oil or other suitable fluid under sufficient pressure be introduced at 1, it will be readily seen that the frame *A* will be lifted clear of the casing, and will actually float on the fluid in the cylinders. Similarly, if the direction of rotation is reversed so that the tendency is to force the frame *A* against the beam *E*, the introduction of fluid under pressure at *2*, will prevent the frame *A* from coming in actual metallic contact with *E*. Since all three cylinders

of the set that may be in action are connected to the same source of fluid supply, the slightest difference in tooth pressure on either side of the middle point of the pinion shaft *F* will cause the frame *A* to yield at the point where the pressure is unduly high. In thus yielding, the excess pressure is relieved, and automatically transferred to the point in the working face of the pinion at which the tooth pressure was, at the instant, below normal.

The broad underlying principle of the design is, therefore,

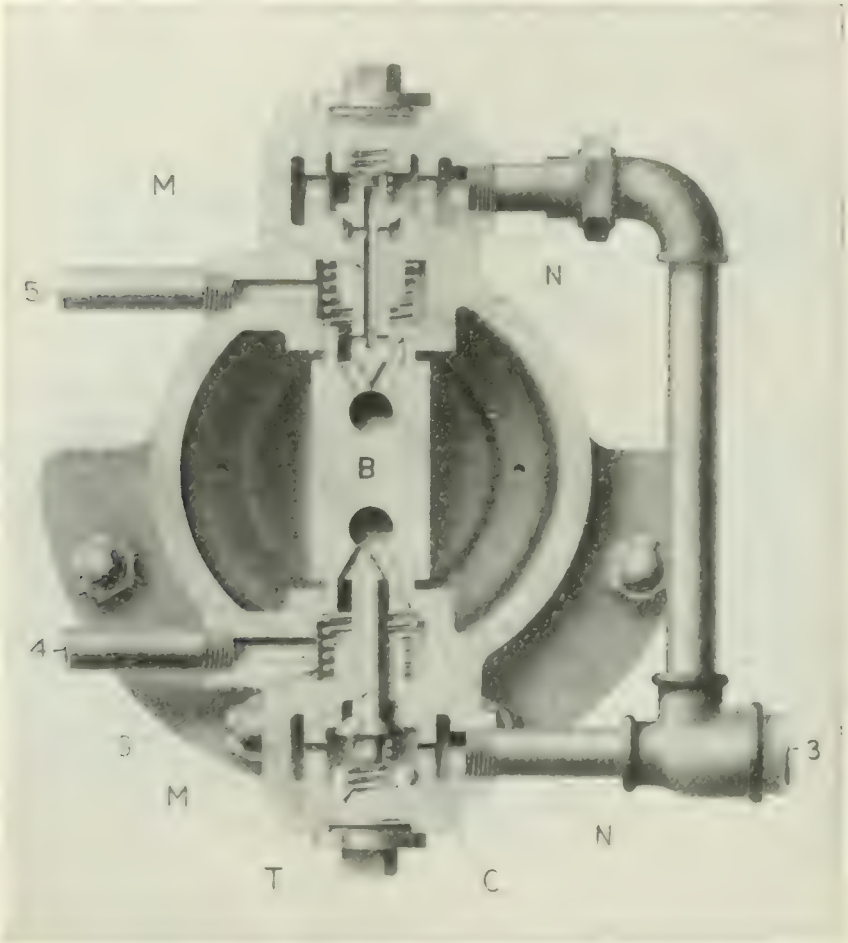


FIG. 4.—SECTION THROUGH OPERATING ARM B AND VALVES ADMITTING TO UPPER AND LOWER CYLINDERS

the supporting of the pinion shaft in a frame which literally floats on oil, and which has no metallic or other rigid connection to the main casing. The practical application of this principle involves the accurate and automatic regulation of the fluid pressure in accordance with the load on the gear. The means by which this is accomplished will be understood from a study of the actual detail sections, Figs. 3 and 4. Fig. 3 is a section through the floating frame at the middle bearing. The frame is split in a horizontal plane for convenience in removing or inserting the shaft and bear-

ings. 1 and 2 are the longitudinal oil passages communicating with the supporting cylinders, and 6 is a duct which conveys lubricating oil at low pressure throughout the length of the pinion frame and distributes it by means of side outlets, to the bearings, and to the pinions. *B* is an arm which projects into the valve box *G*, and which contains passages communicating with 1 and 2. *H* is a link which hinges the frame *A* to the casing *D* so that the slight vertical motion of the frame is multiplied at the end of the arm *B* which controls the oil valves.

For many years it has been known in a general way that if oil be fed to a rotating journal at the point of minimum pressure, it will be carried by the journal to the point of maximum pressure, and if a means of egress is provided, the oil may be discharged

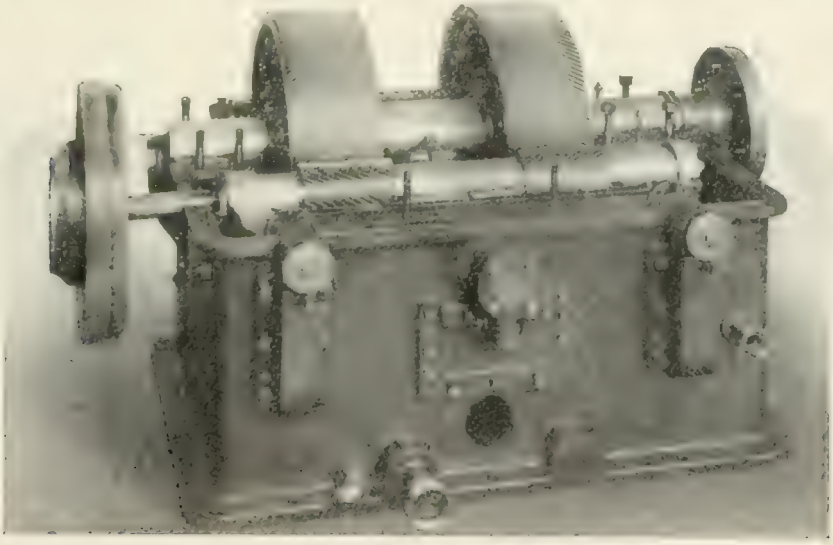


FIG. 5—STATIONARY TYPE OF GEAR WITH COVERING REMOVED, SHOWING FLEXIBLE TURBINE COUPLING TO THE LEFT

against a pressure substantially equal to the maximum bearing pressure. Heretofore, practically nothing has been known, however, regarding the quantity of oil that might be pumped through a properly designed bearing.

In the development of this gear, it was found that by suitably proportioning the bearings and supporting pistons, the former could pump all of the oil required for floating the pinion frame. Referring to the section through the bearing, as shown in Fig. 3, it will be seen that there are small passages connecting the top and bottom of the bearing with the upper and lower cylinders respectively. The bearings draw in oil from the lubricating system, and discharge it through the check valves *L* into the supporting cylinders, and were it not for the automatic regulating mechanism in the valve box *G*,

would build up a pressure considerably greater than is required to keep the pinion bearing frame floating in its normal position.

A cross-section on a larger scale through the valve box *G* is shown in Fig. 4. If the direction of rotation of the pinion is such as to bring the lower set of balancing cylinders in action, the excess pressure will tend to raise the arm *B* slightly, and as the ring valve *N* cannot follow it on account of coming up against a shoulder, the surplus oil will escape into the valve box.

Referring back to Fig. 3, *J* is a floating packing which prevents the overflow oil from spilling directly back into the main casing, and compels it to run off through the drain pipe *K*. This pipe discharges into an open funnel, and the constant overflow of oil is an unfailing indication that the gear is functioning properly. From this funnel the oil may be returned to the main casing to be circulated again through the lubricating system. When starting, it may be desirable, though not absolutely necessary, to supply the oil to the supporting cylinders from an outside pressure source, until the gear attains the normal speed, and the pumping action of the bearings is fully established.

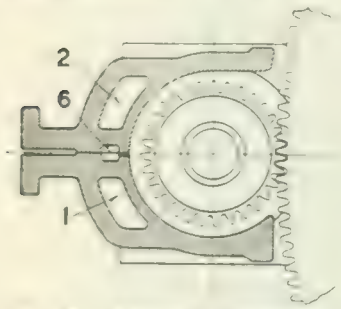


FIG. 6—SECTION THROUGH FLOATING FRAME AND PINION

In Fig. 4 oil from such an outside pressure may be introduced at *3* and led to the upper and lower valves as indicated. If the direction of rotation of the pinion is such as to depress the frame, the arm *B* depresses the ring valve *N*, and the conical valve *M*, pushing the latter from its seat. The stem of the valve *M* is hollow, as shown in the section through the upper valve. When the valve *M* is opened, the oil passes through the hollow stem, as is clearly shown, into the lower circular port in B, and thence to the passage 1 (Fig. 3) which connects with the lower set of cylinders, and is prevented by the check valves *L* from escaping into the bearings. When the balancing pressure has been attained, *B* rises to its neutral position, allowing M to seat and prevent further entrance of oil. If, by reason of a reduction of the load, the oil pressure in the supporting cylinders becomes excessive, *B* rises slightly above its neutral position, relieving the excess pressure in exactly the same way as when the oil is being pumped by the bearings. The total movement of *B* for adjusting over the entire range of load is only a few thousandths of an inch. When the direction

of rotation is reversed, the operation is just the same, except that the necessary functions are performed by the upper valves instead of the lower ones.

From the foregoing description, it will be readily seen that the oil pressure in the supporting cylinders is always exactly in proportion to the torque that is being transmitted. By virtue of this fact, a simple pressure gauge connected inside of the valve *M* will, if the speed in revolutions per minute be known, indicate the instantaneous load on the gear, so that the Westinghouse reduction gear is not only an efficient transmission device, but a most accurate and sensitive dynamometer as well.

The connections to the pressure gauges are indicated at 4 and 5 (Fig. 4). If recording gauges are used instead of simple indicating gauges, and a graphic speed recorder is connected to the gear,

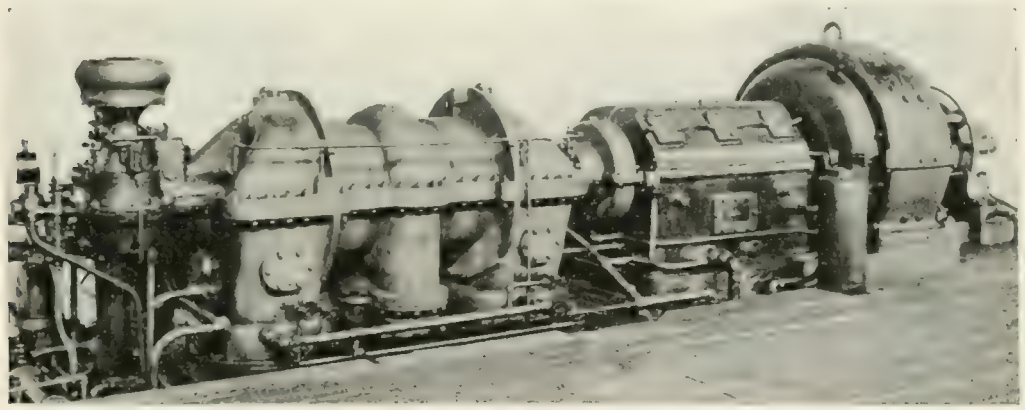


FIG. 7—LATEST TYPE OF GEARED TURBO-GENERATOR UNIT

the charts from these instruments would constitute a continuous log of the power transmitted. The pressure gauges may be located in any convenient position, and as far away from the gear itself as may be desired. The direction of rotation is always evident from an observation of which of the two gauges is indicating pressure at the time.

If the gauges were placed at any considerable height above the gear, their indications would have to be corrected for the hydrostatic head of the oil column. Furthermore, if the gauges were located at a great distance from the gear, there might be some annoyance from leakage, solidification or air pockets in the oil piping. For long distance indications, an ingenious little device has been worked out, which translates the oil pressure to a compressed air supply, which may be conducted to the pressure gauges

wherever they may be located. This translating device is indicated by *O* (Fig. 3).

A section through the floating frame and pinion, Fig. 6, illustrates the simple way in which the lubrication of the gear teeth is accomplished. The frame encloses the pinion except for a portion of the circumference where the teeth engage with those of the large gear. From the passage 6, lubricating oil passes to the pocket in which the pinion is located. The shape of this pocket is such that the oil cannot run out, but must be picked up by the teeth of the pinion. The oil, when picked up by the pinion, is thrown off again by centrifugal force, but owing to the construction of the

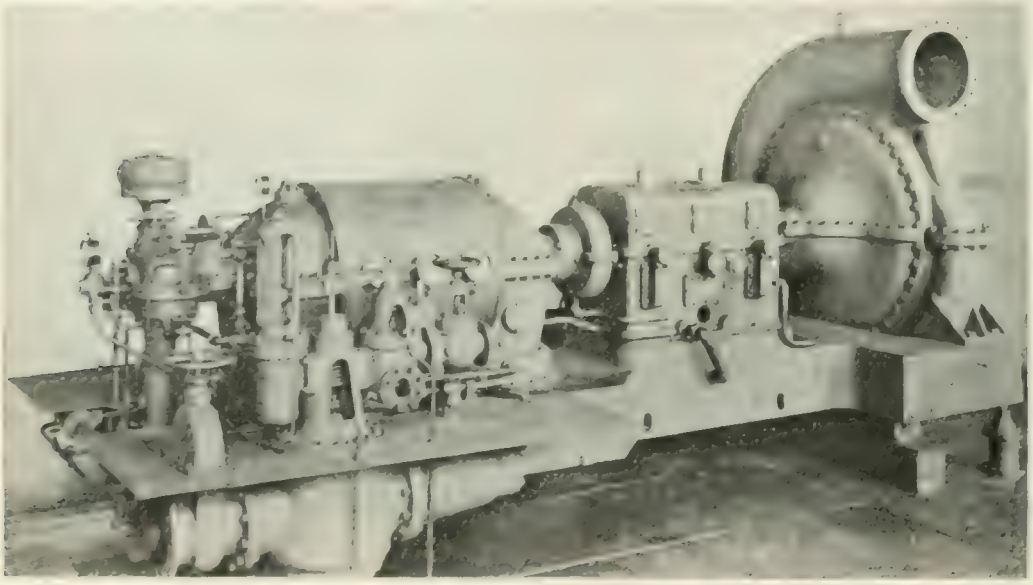


FIG. 8—GEARED CENTRIFUGAL PUMPING UNIT
Homestead Steel Works, Munhall, Pa.

frame, it can escape only by being discharged directly into the teeth of the large gears just at the point of engagement.

In Fig. 1 at the left of the casing is shown a bracket through the upper end of which is a screw adjusted strut bearing against the pinion frame. A similar bracket and strut—not shown in the illustration—are located at the other end of the casing. These struts are for adjusting and maintaining constant the depth of engagement of the gear teeth. They do not interfere with the movement of the pinion frame in a vertical plane.

In order to obtain a flexible drive between the turbine and the gear, and at the same time to keep this gear in close proximity to the turbine, the pinion shaft is made hollow, and the driving shaft passes freely through this bore and is connected to the pinion shaft

at the end furthest away from the turbine. This is an old and fairly well known construction, which has been incorporated on account of its making the apparatus more compact, and not because any novelty is claimed for it.

While this type of reduction gear was originally designed for marine propulsion, in order to harmonize the high speed which is the essential characteristic of an efficient steam turbine, with the comparatively moderate limiting speed for an efficient propeller, its adaptability for other purposes is opening up a field even broader than the one primarily contemplated.

The design of direct-current generators of fairly large capacities, to operate at the high rotative speeds necessary for direct connection to efficient steam turbines, has always presented difficulties that were seemingly unsurmountable. These difficulties have all been eliminated by interposing the reduction gear between the turbine and the dynamo, so that each element of the combination may operate at the speed for which it is best adapted.

Similarly, centrifugal pumps for large capacities at moderate heads are not at all suitable for direct turbine drive, but turbine and pump may be connected through the reduction gear, constituting a highly efficient and attractive unit.

Naturally, for this sort of service in which the direction of rotation is never reversed, only one set of balancing cylinders and regulating valves is required. Figs. 7 and 8 illustrate applications to direct current generators and centrifugal pumps. These are only two out of a large number of new opportunities for the steam turbine that will present themselves as soon as it is realized that the handicap of inherent high rotative speed can be removed by a thoroughly reliable and durable system of gearing having an effiiciency of over 98.5 per cent and that such a system is now an accomplished fact.

In addition to the two 4,000 horse-power gears installed on the U. S. S. "Neptune," twelve 1,000 horse-power and 2,000 horse-power sets have been sold for driving direct current generators and for other purposes. A number of these have already been in service for some months, running at speeds as high as 3,600 revolutions per minute, with results that are most gratifying in every particular.

LOW PRESSURE TURBINES

WHY TO USE, WHEN TO USE AND HOW TO USE

P. M. LINCOLN

THE use of low-pressure turbines in connection with existing reciprocating engine plants is becoming more and more general. There are a great many cases where the installation of this type of apparatus has proved highly successful and there are a great many more plants where the low pressure turbine can be installed with great benefit to the user. It is the intention in this article to discuss some of the conditions which make its installation desirable, as well as the reasons why such an installation can be made economically. The limited space available will evidently make it impossible to treat of all the cases under which it may become advisable to use the low pressure turbine. There are many ways in which steam may become available for low pressure turbine work and many ways in which the power thus made available may be used. Each condition of steam supply may be combined with any of the methods of power utilization, making the number of combinations very large. This article will deal more with the methods of utilization of the power than the methods of steam supply.

WHY TO USE

The fundamental reason for the use of the low pressure turbine is that the turbine is, in general, much more efficient than any other type of prime mover, when using steam at low pressure. A reciprocating steam engine can utilize steam between the limits of ordinary boiler pressures and atmospheric pressure as efficiently as a turbine. However, in the use of steam from about atmospheric pressure to that maintained in the condenser, the turbine is a very much more efficient machine than the reciprocating engine can possibly be. This higher efficiency is inherent and is due to the fact that the turbine allows the continual expansion of the steam from the atmospheric pressure right down to the vacuum maintained by the condenser, while the reciprocating engine, to accomplish the same result, would have to have low pressure cylinders of so large a volume and of so great a cost that efficient expansion down to the condenser pressure becomes out of the question. Further, the fact that the cylinder walls in a reciprocating engine are colder than the compressed steam at the beginning of

the stroke and hotter than the expanded steam at the end of the stroke causes partial condensation at the beginning of the stroke and partial reëvaporation toward the end, thereby making the expansion of steam to the vacuum maintained in the condenser still more difficult than would otherwise be the case.

On account of this limitation of the reciprocating engine, it has been the practice in the past to equip reciprocating engines with condensers which would only maintain a vacuum of from 20 to 25 inches. When using turbines, it is desirable to maintain the highest possible vacuum on account of the higher economies thus obtainable and it is customary to run this vacuum as high as the temperature of the condensing water will allow, usually up to 28 inches and sometimes even as high as 28.5 or 29 inches.

To indicate in a rough way about how much betterment in economy may be obtained by the use of low pressure turbines, the following statements may be taken as approximately correct:—

A simple Corliss engine running non-condensing will have a full-load water rate of approximately 35 lbs. per kw-hr.

A compound engine running non-condensing will have a full-load water rate of approximately 29 lbs. per kw-hr.

A compound engine running condensing will have a full-load water rate of approximately 21 lbs. per kw-hr.

A compound engine in connection with a low pressure turbine will have a combined full-load water rate of about 17 lbs. per kw-hr.

The above figures must be taken as approximate, since the actual water rates depend upon size, boiler pressure, superheat, vacuum, etc. However, the relative values, when these conditions are fixed, are nearly correct.

The advantages of using a low pressure turbine may be better appreciated when one considers the fact that in the perfect steam engine there is nearly as much energy available in a given amount of steam from the atmospheric pressure to a 28 inch vacuum as there is in the same amount of steam from boiler pressure to atmospheric pressure. The energy available to any steam engine is roughly proportional to the range of the temperature through which the steam passes when used in that engine; that is, it is roughly proportional to the difference in the temperature between the steam admitted and the steam discharged. A perfect engine would convert all the available energy into mechanical energy. To state the case somewhat more exactly: Starting with dry steam at 105 lbs. boiler pressure, there is as much available energy in a given amount of this steam from atmosphere to 28 inches vacuum

as there is from 105 lbs. boiler pressure to atmosphere. With the combination of a reciprocating engine taking its steam at boiler pressure and discharging all of its exhaust into a low pressure turbine, which in turn discharges its steam into a condenser, there will be, in general, somewhat more energy available to the reciprocating engine than to the low-pressure turbine. This is due to the fact that boiler pressures are usually higher than 105 lbs gauge.

The actual division of load between an engine and a low pressure turbine using all the steam exhausted by the engine will, of course, depend upon the exhaust pressure of the engine. The above relation holds only when the engine exhaust and the turbine inlet are both at atmospheric pressure. If the engine exhaust and the turbine inlet pressures are above atmospheric pressure, the available engine output is thereby decreased while the turbine output is increased. Of course, the contrary is true when the engine exhause pressure drops below atmosphere. More will be said on this further on in this discussion. So much for the "why" of using low-pressure turbines.

WHEN TO USE

The next question that naturally presents itself is, "What are the conditions which will justify the installation of low-pressure turbines?" The main reasons which justify such an installation are two, viz.:

First, to increase capacity, and
Second, to better economy.

Either one or both of these reasons may justify the installation of the low-pressure turbine. What the prospective user must determine is whether or not either or both of these advantages are sufficient to justify the expense for new apparatus and other changes which the adoption of low-pressure turbines necessarily entails. In addition to the question of economy, there are some general conditions that must be fulfilled before the installation of the low-pressure turbine is justified.

One of the prime conditions for the efficient operation of a low-pressure turbine is the maintenance of a good vacuum, and unless conditions of condensing water, etc., are such that a good vacuum can be maintained, the reason for installing low-pressure turbines largely disappears. Where natural sources of condensing water cannot be obtained, it is a common practice to use cooling

towers, spray nozzles or some other means of cooling the condensing water by bringing it into sufficiently close contact with the air, so that part of the water is evaporated. The amount of water thus evaporated must be at least equal to the amount of steam condensed, since the latent heat of the condensed steam that has been taken up by the circulating water must be dissipated in turn by the evaporation of a portion of the circulating water. In addition to this, leakage, loss by fine spray, etc., must be allowed for, which in actual practice, demands the use of 1.5 times to four or five times the amount of the condensed steam, and even higher in plants of improper design and insufficient attention.

Moreover, it should be borne in mind in selecting condensing apparatus, that when using turbines, either high or low pressure, it pays to go after a high vacuum. As indicated above, the advantage of the low-pressure turbine is that it allows the complete expansion of the steam right down to the maximum vacuum that the condensing apparatus can maintain. Hence it follows that the economy of a steam turbine continually increases as the vacuum is increased. If it is intended to apply a low-pressure turbine to a case where reciprocating engines have been previously running condensing, it does not necessarily follow that a gain in economy will be obtained if the same condensing apparatus is used. For reasons given above, the condensing apparatus for reciprocating plants is usually not good enough to obtain the full measure of economy which can be obtained by low-pressure turbines, and when installing low-pressure turbines it will pay in practically all cases to install new condensing apparatus with them.

Another point that must be considered is the possibility of operating the reciprocating engines at such exhaust pressures as the use of low-pressure turbines will demand. Often the relative piston areas of compound engines are such that there will be "looping" at certain loads, if the exhaust pressure be increased to atmosphere or thereabouts. There results a pounding of the valves which makes it difficult or impossible to operate the engine. This condition is, of course, more apt to obtain on low loads than on high and is, therefore, one which does not always arise, owing to the fact that the exhaust pressure on the engine automatically decreases with load, as will be shown later.

Briefly, then, the "When to use" low-pressure turbines may be summarized as follows:—

1—When increased capacity is desired, or
2—When better economy is desired,

Provided good condensing conditions can be obtained and the engine design is such as to lend itself to the changed conditions.

HOW TO USE

The foregoing discussion has been of a preliminary nature and has been more or less for the purpose of introducing the subject of how best to use the power that is available by the low-pressure turbines. The most practicable method of making available the power from a low-pressure turbine is to turn it into electricity. The speed of such a machine is inherently so high that it is impracticable to take the power out of the turbine by mechanical means except, possibly, by the reduction gear, which is being manufactured by The Westinghouse Machine Company. This limitation can hardly be called a disadvantage, since the power is usually desired in the shape of electrical energy and not as mechanical energy and in almost every case it is not only necessary, but desirable to use an electric generator as the means of making available the output of the low-pressure turbine.

A point that deserves careful attention is the variation in the relative loads carried by engine and turbine as the combined load on these units varies. Assume an engine exhausting into a low-pressure turbine and the turbine into a condenser. The one thing that is apparent is that the total difference in the pressure between boiler and condenser is divided between the engine and turbine such that the sum of the pressure drops through both is equal to said difference. It is further true that the pressure drop through a turbine varies directly in proportion to the amount of the steam flowing. Assume that at full load the exhaust pressure of the engine, (and, therefore, the inlet pressure of the turbine) are at atmospheric pressure. As the load decreases, the amount of steam flow decreases. This, of course, will have the effect of increasing the pressure range, and therefore, the temperature range of the engine, while decreasing the pressure and temperature range of the turbine. Recalling that the available energy in a given amount of steam is in proportion to its decrease in temperature, as it passes through any thermodynamic engine, it can readily be seen that as the combined load decreases, the proportion of that load that will be assumed by the engine increases at the expense of a decrease in the proportion carried by the turbine.

Conversely, as the combined load increases, the drop of pressure through the turbine increases, the inlet pressure to the

turbine, together with the back pressure of the engine exhaust, rises, the temperature range of the turbine increases at the expense of the temperature range of the engine and consequently, the proportion of the load carried by the turbine increases at the expense of the proportion carried by the engine.

This variation in the relative amounts of energy available to engine and turbine is shown approximately in Fig. 1. In this curve it is assumed that the engine receives dry steam at 160 lbs. boiler pressure and exhausts it into the turbine. The condenser carries a vacuum of 28 inches and the engine exhaust is assumed at the atmospheric pressure when the combined load is 100 percent. The actual distribution of load between the two units will depend largely upon the individual conditions surrounding each installation and only a rough idea of the comparative variation at different loads may be obtained from Fig. 1. In laying out an equipment of low-pressure turbines and auxiliary apparatus, this variation in relative loads at different points on the load curve must be borne in mind. The problem of applying the low-pressure turbine may best be considered under a number of cases, as follows:—

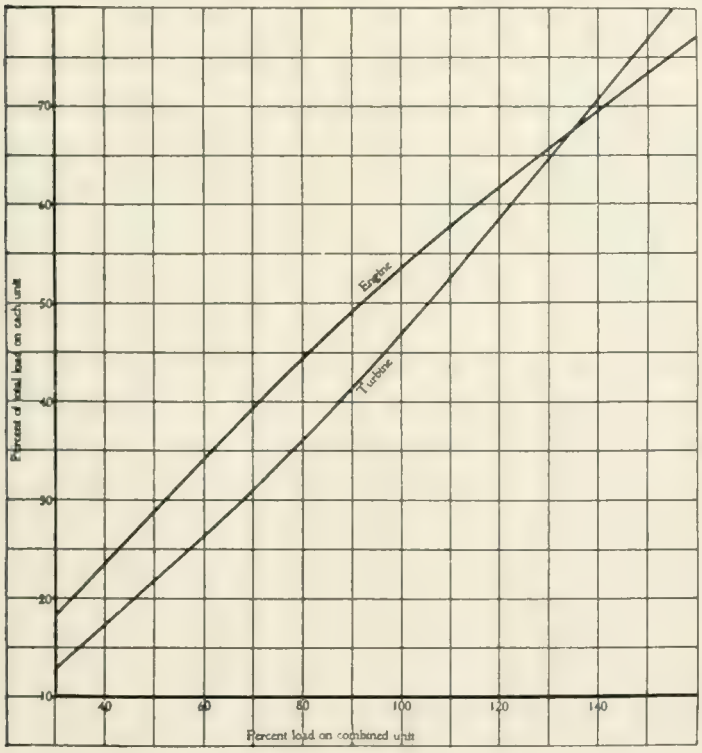


FIG. 1

1—Engine driving mechanical load and turbine to be connected to same load.

2—Engine driving mechanical load and turbine to drive an independent electrical load.

3—The engine driving an electrical load and the turbine to put its power into the same system. As a corollary of No. 3, the differences between the alternating and the direct-current system should also be considered.

Case 1—When a low-pressure turbine is used in connection with an existing engine driving, for instance, a line shaft and it is desired to add the energy of the low-pressure turbine to the same line shaft. One method of taking care of such a case is to attach to this line shaft, either by belt or other means, an electric motor of sufficient capacity to absorb all the energy of the low-pressure turbine under any normal conditions. The operation of this combination is as follows:—

The engine delivers its quota of power to the line shaft. The exhaust of the engine flows through the turbine, producing a certain amount of additional power. This power appears in the generator as electrical energy and is delivered to the line shaft by the agency of the motor. The speed governing in such a case is all done by the engine governor, exactly as though the low-pressure turbine were not present. When the speed tends to rise on account of a decrease of load, the governor acts to cut off a portion of the steam, thereby decreasing the power put in by the engine. This also causes a decrease in the amount of steam through the low-pressure turbine and consequently, a decrease in the amount of power put into the line shaft by the turbine. The speed of the motor is, of course, in proportion to that of the line shaft (being belted to it) and whether the motor be induction or synchronous, its speed always bears a certain relation to the speed of the generator. The speed of the line shaft is governed by the speed of the engine governor and the speeds of the motor and generator bear a definite and constant relation to the line shaft speed. Hence, the action of governing is exactly the same as if the low-pressure turbine were not present. The main thing to look out for in this application is that the generator is large enough for the turbine and that the motor is large enough to transform all the energy which can be produced by the generator. Either a synchronous motor or an induction motor may be used.

An alternative to the above is to use a low-pressure turbine direct-connected to a gear and mechanically connected in some manner to the line shaft. This method would obviate the necessity of converting all the energy of the low-pressure turbine into electrical energy and then reconverting it into mechanical energy by the motor. If the use of the low-pressure turbine were confined to the conditions of Case 1, there would be little use for the electrical engineer in connection with it, since the reduction gear can apply

the energy available from a low-pressure turbine to a mechanical load, both with greater efficiency and with less cost than the generator and motor method. However, this fact has little bearing on the general problem, since there is practically never a call for a mechanical load only. The modern plant almost always uses electrical energy in some form and the best solution of the problem will be, in general, to convert the energy of the low-pressure turbine first into the electrical form and then distribute it as required.

Case 2.—When the engine carries a mechanical load and the turbine carries an independent electrical load. This is the condition that is encountered perhaps more frequently than any other, since it is a natural step in the extension and enlargement of an existing mechanically-driven mill. In general, the solution of the problem is very similar to Case 1; namely, the connection of a synchronous or induction motor to the mechanical load and the transfer of power from the low-pressure turbo-generator to this load by the motor or the transfer of a portion of the power of the engine into the electrical load by using this auxiliary machine as a generator, as the case may be. In this case, however, the question of size of the necessary motor is one of the things to be determined. In Case 1, the size of the motor is easily determined, since all of the power of the turbine must be utilized through the agency of the motor. In Case 2, however, a large part of the power may be used by the independent electrical load and as a consequence, the size of the motor need not be as large as it would be in Case 1.

The conditions assumed for Case 2 are shown diagramatically in Fig. 2. The considerations which govern the size of the motor is not a difficult one to determine. It is quite evident that the combined output of the engine and generator in Case 2, is exactly the same as the total combined electrical and mechanical load. In other words, the combination of mechanical and electrical load is driven by the combined output of the reciprocating engine and low-pressure turbine. If the mechanical load be designated by M_2 and the electrical load by E_2, as indicated in Fig. 2, and if further the mechanical output of the engine be designated as M_1, and the electrical output of the turbo-generator by E_1 it is quite evident that the following relation must be true; namely, $M_1 + E_1 = M_2 + E_2$. It is further evident that if the mechanically-driven load is larger than the output of the engine, the difference between the two must be derived from the motor E_2, and if the electrical load

E_3 is greater than the output of the generator E_1 the difference must be furnished by the motor E_3 operating as a generator. As a consequence, it is quite evident that the following condition must also be true: $E_3 = M_2 - M_1 = E_1 - E_2$.

The above, therefore, is the method by which the size of the motor E_3 may be determined. It requires simply a knowledge of the relative engine and the turbine outputs and the value of the mechanical and the electrical loads. One limit of the size of the motor will be determined by assuming that there was no mechanical load. In this event, the motor E_3 would become a generator and the total output of the engine M_1 would be turned into electrical energy by the generator E_1 and would appear in the electrical circuit. This case would be similar to case 1, with the exception that all the energy finally appears as electrical energy instead of mechanical energy and the motor which in Case 1 transformed all the energy of the turbine into mechanical energy and now acts as a generator and turns all of the energy of the engine into electrical energy.

The question of regulation would be taken care of in exactly the same manner as in Case 1; that is, the engine governor would regulate the speed of the entire system. The speed of the motor E_3 whether operating as a motor or a generator, would bear a definite relation to the speed of the engine, and the generator E_1 would be kept in synchronism with the motor; thus the speed of the entire equipment would be regulated by the original engine governor.

The same regulation in speed would take place, no matter what the size of the motor so long, of course, as the torque which is necessary for this machine to develop, either as a motor or generator, is not sufficient to cause it to fall out of the step with the generator E_1. So long as this is the case, it is very evident that the speed regulation of the entire system may be taken care of by the governor of the original engine M_1.

In determining the size of the motor, it must be borne in mind that the relative loads carried by the engine and low-pressure turbine may vary as the load changes. This point is fully explained earlier in this article. A size of motor, therefore, which may be correct for one loading of the combined units, might not be correct for another loading. Assuming, for instance, a 1 000 horse-power engine in connection with which is installed a 750-kilowatt low-

pressure turbine. Full combined load on this outfit would be about 2 000 horse-power, divided into such proportions that approximately 55 percent will be developed by the engine and 45 percent by the turbine. In other words, approximately 1 100 horse-power would be developed by the engine and 900 by the turbine. Now assume that the load conditions change such that 25 percent overload is demanded, or 2 500 horse-power total. Under the new condition, the division of the load between the engine and the turbine is such that they are very nearly equal, and as a consequence, the engine

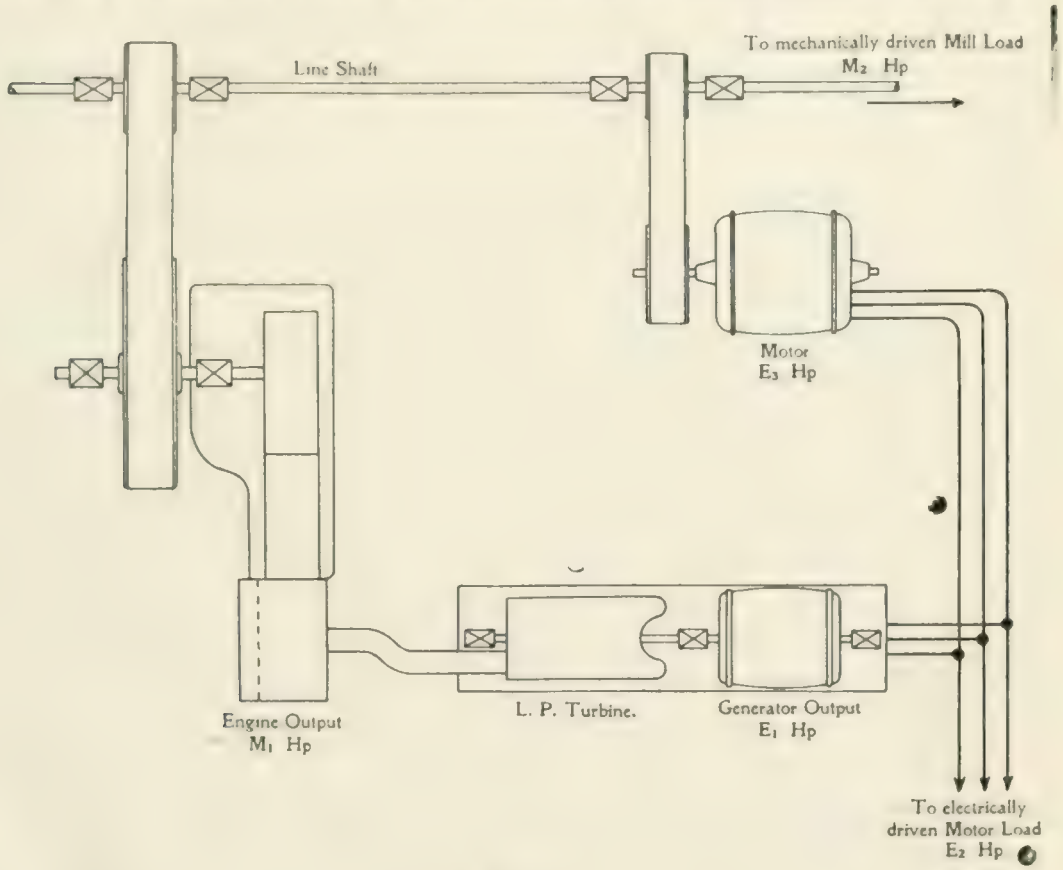


FIG. 2.

has increased its output from 1 100 to about 1 250 horse-power, while the turbine increases its output from 900 to about 1 250 horse-power. Further, if it is assumed that a motor of given size connecting the mechanical and electrical systems together would not be overloaded by the first condition, it might be readily overloaded by the second. The actual determination of whether the motor would be overloaded by the increasing power, would depend upon whether the increase was in the mechanical part of the load or the electrical part of the load, and whether the motor was originally loaded as a generator or a motor.

There are certain conditions which make it advisable that the motor which forms the connection between the mechanical and the electrical systems, should not become too small a proportion of either of the systems. Theoretically, if the electrical loads were always exactly equal to the output of the generator E_1 and the mechanical load were always equal to the mechanical output of engine M_1, there would be no need of motor E_2 so far as transferring energy from one system to the other is concerned. On the other hand, the use of the motor E_2 is necessary for speed regulating purposes. Even assuming the above equality, this motor is the only thing which keeps the speed of the turbine always in a given relation to that of the engine. If it were not for the presence of the motor, the turbine might increase or decrease its speed by a certain amount and still equilibrium remain undisturbed; in other words, the mechanical load would always remain equal to the output of the engine and the electrical load would always remain equal to the output of the turbine, independent of the relative speeds. Therefore, even under the conditions of an equality, thus assumed, the presence of the motor E_2 would be necessary for the purpose of relative speed regulation.

It is further evident that if the motor E_2 were very small compared to the generator E_1, any sudden disturbance either in the electrical circuit or in the mechanically driven load, as for instance, a short-circuit or the sudden throwing off of a belt, might cause the motor to drop out of step, thereby interrupting the speed regulation which is so evidently essential to the entegrity of the system.

Practice has demonstrated that a motor E_2 which is as small as 50 percent of the capacity of the generator E_1 will operate satisfactorily. Whether the size can be reduced materially below this is a question upon which there is insufficient data from practice to give a definite answer. Considerations given above, however, still indicate that there is a limit below which it is unsafe to go and the writer's judgment would place this limit at not very far below 50 percent of the generator capacity.

The above outlines the proper practice when it is possible to tie the mechanical and electrical systems together by a motor (which may at times become a generator). Under the above described conditions the problem of speed regulation for both the mechanical and electrical systems is a simple one, all speed regulation depending upon the governor of the primary engine. How-

ever, there are other conditions in which the above arrangement is impracticable. For instance, suppose that the steam for the low-pressure turbine instead of coming from a single unit driving a single mechanical load, is taken from a heterogeneous lot of engines driving miscellaneous mechanical loads that are in nowise connected together or dependent upon each other. Since, in such cases, it is impracticable to connect a motor to the engines driving this mechanical load, it manifestly becomes impossible to tie together the electrical load and mechanical load as described above. In this event it is necessary to apply some separate means of speed regulation to the electrical system operated by the low-pressure turbine, and this leads directly to the necessity of a governor on the inlet to the low-pressure turbine. In turn, this means either one of two alternatives. First, there must always be available from the various sources of low-pressure steam a sufficient amount of steam to carry the electrical load under any condition, or, second, there must be some means of supplying the electrical load from other sources of power should there at any time be a deficiency in the supply of low-pressure steam. There are, of course, variations in the supply of low-pressure steam from a heterogeneous lot of engines, and there is also bound to be some variation in the load on an electrical system. If we rely upon a low-pressure turbine for the entire supply to the electrical system, the minimum amount of low-pressure steam must always be capable of supplying the maximum demand on the electrical system. When this is true there is necessarily a considerable amount of this low-pressure steam wasted.

One way to overcome this is to adopt the second alternative mentioned above. This usually takes the form of a high-pressure element in the turbine which may be opened to take high-pressure steam whenever the low-pressure steam supply is insufficient for the electrical load. Or a reducing valve can be used to reduce the high-pressure steam to the proper pressure for the low-pressure turbine.

Another of the disadvantages of this method of operation is that the pressure in the low-pressure steam supply must always be above atmosphere since any attempt to place a governor upon the low-pressure system when that pressure is below atmosphere would simply result in the admission of air instead of the escape of steam. There are a number of other alternatives which might be men-

tioned in this connection, but which lead to so extensive treatment of the subject, as hardly to be open for discussion in so brief an article as this.

The above limitations do not by any means make it inadvisable to use low pressure turbines for these conditions. They simply mean that not so large a proportion of the available low-pressure steam can be utilized as would otherwise be the case if it were possible to connect the mechanical and electrical systems together by a motor. In fact, one of the most promising fields for the low-pressure turbines is in connection with steel mills and similar industries, where the connection of a motor to the engines furnishing the low-pressure steam supply is impracticable. Many such plants are now using non-condensing engines and are wasting enough steam to add at least 75 percent to the power of the original plant. The fact that it is not possible to recover the entire 75 percent does not at all mean that it is impossible to recover any of it. All that can be recovered is clear gain whether it be 75 percent or a smaller proportion of the original power.

Case 3—When the engine carries an electrical load and the low-pressure turbine is to be connected to the same load. In this case the solution of the problem is extremely simple. It is simply necessary to connect the low-pressure turbo-generator to the main bus-bar. The speed regulation is entirely automatic, since the low-pressure generator must always remain in synchronism with the engine-driven generator, the frequency of which is fixed by the engine. The engine speed is fixed by its governor and as a consequence, the speed regulation of the whole system depends upon the primary engine governor in exactly the same manner as in cases *1* and *2*. In thise case, there is, of course, no necessity for a motor to connect together any mechanical and electrical systems as is necessary in cases *1* and *2*.

If the system is a direct-current one, instead of alternating current, conditions are very little changed. In the alternating-current system, the low-pressure turbine is held in exact synchronism with the generators driven by the engine, so that the relative speeds do not vary. If the direct-current system is in use, the same will be true within certain limits. As the load varies on the generator driven by a low-pressure turbine there will be a slight change in the speed, its amount and direction depending upon the compounding characteristics; but this is not suf-

ficient to cause any material difference between the direct and alternating-current cases.

The general question of automatic protection of generators connected to low pressure turbines and of the motors used in cases *1* and *2*, may be of interest to discuss:—

In the author's opinion the use of any overload protection with such generators and motors will, in the long run, be found to have more objections than it has advantages. The reasoning that leads to this conclusion is as follows:—

Alternating-current machines are usually guaranteed to carry full-load with a rise in temperature of not more than 40 degrees C. They will further carry 25 percent overload continuously with a rise in temperature of not more than 50 degrees C. Further, a standard guarantee often states that such machines will carry 50 percent overload for one or two hours with a rise in temperature of 60 degrees C. Should it be desirable the machines will carry two or three times their normal load for a length of time which would probably be at least 15 minutes without incurring a rise in temperature that would damage the apparatus. It is further true that on dead short-circuit, a generator or motor cannot, under usual conditions, give more than three times full-load current on account of the armature reaction. It follows, therefore, that under the worst conditions a motor or generator would probably stand short-circuit without serious damage for a period which would approach 15 minutes.

A proper safety device for the protection for such a piece of apparatus should have the same thermal characteristics as the apparatus itself; that is, it should be capable of disconnecting the apparatus after it has operated for one or two hours at 50 percent overload, and it should also be capable of not disconnecting the motor after it has operated at three times full-load for a period of about five or ten minutes. There is not a circuit-breaker made or that can be made that has any such characteristics. In other words, the thermal capacity of any fuse or overload circuit-breaker is of necessity vastly smaller than the generator or motor which it must protect. If a fuse or circuit-breaker be used, and set at 50 percent overload, it would probably be set so low as to be coming out continually. If, on the other hand, it were set up to two or three times full-load, it would not protect the apparatus on overloads. If such a piece of apparatus were installed and

set at such a point that it came out frequently, its tripping point would undoubtedly be set up by the operator until it no longer came out. When set up to this point, it would no longer have the protecting value which is desired.

The problem here is exactly the same as that of protecting alternating-current generators when operating in parallel. In former years it was the general practice to protect alternators in parallel with automatic devices. Experience has proved that the automatic devices in the generator circuits, in general, gave more trouble than they prevented, and, as a result, these automatic devices have been almost universally discarded and standard practice at the present time is to install alternators with no automatic protection whatever between them and the bus-bars which they feed. The prevention of generator or motor burnouts must depend upon the use of common-sense and intelligence on the part of the customer in loading the apparatus. It is impossible to make any protective device which is fool-proof and which is not subject to being set at such a point as to make it ineffective.

The fact that alternators or synchronous motors cannot give more than 200 or three times full-load current, even on short-circuits, makes them self-protective to such a large extent that it is considered unwise and unnecessary to install automatic overload devices in connection with them.

The question has been asked—"What would happen should the condenser of the low-pressure turbine fail?" This will depend, to a very considerable extent on the size of the synchronous motor as compared with the electrical load which it is obliged to carry during such an emergency. If the synchronous motor is not loaded as a generator to a point which will exceed double its normal capacity, it is my opinion that the machine will keep on generating a sufficient amount of power to keep the motors running, provided it received a sufficient amount of power from the engine. In this case, the apparatus in the mill would be kept going at probably a reduced speed until the vacuum could be reestablished. Also the turbo-generator attached to the low-pressure turbine would be kept in synchronism by current from the motor, and the only thing to reestablish proper service would be simply the reestablishment of the vacuum in the condenser. It would, therefore, be of great advantage to eliminate all auto-

matics between the synchronous motor and the bus-bars in such an event, since the only thing necessary to reëstablish service would be simply to get back the vacuum on the condenser. If, on the other hand, automatic devices were put in between the machine and the bus-bars, it would be necessary to re-synchronize the tie-in motor and to start up all the motors that would be shut down when the automatics opened. If a Tirrill regulator were provided upon the system, the proportion of overload which might be carried successfully would be increased. It might be possible to carry as high as 2½ times full-load current for a short time on the motor and possibly even more without having it drop its load. If, however, the electrical load on the motor is too great for it to carry, it will mean simply that the voltage on the system will drop to such a point that the induction motors will stop. The synchronous motor acting as a generator, would still continue to circulate current, but on account of armature reaction, the amount it would circulate would not be sufficient to damage itself for a period probably longer than five or ten minutes—long enough certainly for properly trained attendants to open the necessary circuits and get things moving towards the re-starting of the whole electrical equipments, as would be necessary in this case.

There are many more things that might be said about the "why, when and how" to use low-pressure turbines, but in a brief treatment, such as this, many things must necessarily be left unsaid. The low-pressure turbine has been used in the past and is bound to be used much more extensively in the future. If these few pages lead to the use of this device in some places where its use will be beneficial, or prevent its use where conditions are not suitable, the object of this article will have been accomplished.

NOTES ON THE DESIGN OF TRANSFORMERS

E. G. REED

THE problem in transformer design is to lay out the apparatus so that it will give the best service to the user and at the same time will be saleable at a profit. To meet the first requirement, the designing engineer must therefore study service conditions, so that the apparatus will operate satisfactorily under all normal conditions. To meet the second requirement, he must consider all of those points which have to do with minimizing the manufacturing cost for the given service conditions. Thus, the designs must involve the minimum amount of material necessary to insure the best results and must be capable of being built with the least possible complications in manufacture. In short, a successful design is a proper compromise between the demands of good service and of low first cost.

It is evident that these two requirements may be antagonistic; since, for instance, bettering the performance will increase the cost, and vice versa. As a rule the user of transformers is willing to pay for an article of superior merits if the saving in its operation in more than the cost of carrying the additional investment represented by its greater cost. The relations of the various factors entering into a design which meets the above conditions are indicated below. Only the most important feature will be discussed, with the idea of giving a broad and general conception of transformer design.

- Transformer Design
  - Service Requirements
    - Life
    - Efficiency, Regulation
    - Convenience in operation
    - Size and weight
  - Cost Requirements
    - Material
    - Shape and proportions
    - Manufacture

Transformer Life. The life of a transformer depends largely upon its operating temperature and its insulation. No insulation known at the present time, applicable to transformers, can operate continuously at 100 degrees C. without deteriorating. On the other hand, an improper application of insulation will result in increased heating. The matter of transformer heating may be analyzed as follows: The temperature of the windings of an oil insulated transformer, for instance, depends partly on the tempera-

ture of the oil in the transformer case, and partly on the temperature gradient between the oil and the actual copper in the coil. The temperature of the oil in the transformer is proportional to the total transformer loss (i.e., iron plus copper loss), while the temperature gradient between the windings and the oil is proportional to the copper loss. The necessity of keeping a low temperature gradient between the oil and copper involves the use of ventilating ducts through the windings, and the temperature gradient in a good transformer should not much exceed 10 degrees C. The importance of a low temperature gradient is particularly apparent when a transformer is overloaded, as the gradient increases in proportion to the square of the load. The expedients of employing corrugated or tubular metal cases for the larger self-cooling transformers, and water cooling for very large units, for cooling the oil are important factors in transformer design.

Performance. In considering the question of performance of transformers, it will be advisable to distinguish between two general classes, viz., distributing and power transformers.

Transformers of the distributing class take current from the higher voltage distributing lines and deliver it directly to the power user. Distributing transformers are ordinarily used on normal 2 200 volt primary lines, but are also sometimes used on lines as high as 17 000 volts. Transformers of this class must be designed with low iron loss and good regulation. The iron loss must be low, since they are in service continuously. On the ordinary distributing system there are a relatively large number of small transformers whose aggregate losses naturally become a very important consideration. Further, since the service usually includes lighting, very close regulation is demanded. The design problem in this case, therefore, becomes one of making a transformer, whose losses are practically fixed by service conditions, for a minimum cost of material.

Transformers of the power class are built for use in central stations, for raising and lowering the voltage for the purpose of long distance transmission, and for corresponding use in sub-stations. Since power transformers are usually fully loaded, there is no demand for a condition of lower iron loss than copper loss, and these losses are usually made about equal in value. The losses in transformers, assuming the same constants of design, increase only as the three-fourths power of the output. Therefore, with units of larger and larger size, a point is soon reached where

the losses are relatively small and more than satisfy service requirements in this respect. Hence, it then becomes a question of making the cheapest transformer possible, without giving special attention to reduction of the losses. The methods of carrying out designs according to these two methods will be investigated later.

Convenience in Operation. The requirements of operation have led to the development of the various familiar types, whose distinguishing features may be reviewed as follows: Pole-type and manhole-type distributing transformers are provided with sealed, weather-proof, and in the case of manhole transformer, water-tight cases. Power transformers are either self-cooled, cooled by air blast, or water cooled. Since power transformers are usually located in the central station or sub-stations, they need not be made moisture or water-proof, as is required of the distributing transformer. Self-cooled, oil insulated power transformers of sizes up to about 500 k.v.a. capacity are mounted in tanks with corrugated sheet metal sides cast in top and bottom castings, with a sheet iron cover for the tank. Recently self-cooled transformers up to 3 000 k.v.a. capacity have been built, the cooling surface being secured by the use of a number of tubes, extending out from the lower part of the smooth boiler iron tank and entering again near the top, through which the oil may circulate. The cooling effect of the surface of the tubes is much greater than that of the corrugated surface just referred to. Such transformers are used where water for cooling purposes is very costly, or is not available, as is often the case with isolated sub-stations. For very large transformers some more effective method of coling must of necessity be used, such as in water cooled transformers, in which water is forced through pipes submerged in oil in the transformer case.

Materials. Before a design is attempted, it is, of course, necessary to understand the characteristics of the materials used in the construction of a transformer, i.e., the resistance constants of the copper, the true and apparent watts, or permeability constants of the sheet iron, and the mechanical and electrical properties of the insulating materials. The copper conductors are usually insulated with cotton covering, and must be of proper size and shape so that they can be wound readily, and so that excessive eddy currents are not set up by the leakage magnetic fields.

The thickness of the best transformer iron is from 0.0125 to 0.0172 inch. At about 10 000 magnetic lines of force per square

centimeter, the best irons have losses of between 1 and 1.5 watts per pound true loss and about 2.5 watts per pound apparent watts, which represents a power-factor of about 50 percent at that density. In design work, curves giving the true and apparent watts for different densities are required. It is found that the iron curve up to 10 000 or 12 000 lines per square centimeter can be expressed by the relation that the watts per pound of iron increases as the 1.7 power of the induction. From this, the importance of having a good grade of iron in the transformer will be realized, and it will suffice to state that the cost of the active material in the transformer will vary as the 2.4 power of the quality of the iron. That is if iron can be secured having ten percent less loss than that being used in a certain transformer, the cost of the iron and copper can be reduced approximately 24 percent. These results are of course theoretical values based upon the exponent of 1.7 referred to above.

Before starting a design, it is necessary to settle on the type of insulation to be used. If the percentage of space occupied by the copper in the total cross section of a transformer winding be designated as the "space factor", it may be seen that, with other quantities assumed as constant, the cost of active material will vary about as the space factor. This shows the importance of a high space factor. Often the deciding factor in the selection of the type of winding is the relative space factor, assuming the same insulation strength in each. In general there are two typical methods of insulating transformers, the first being the method of using treated material in the winding and assembling of the coils; the second is to make the winding of untreated material and impregnate the completed transformer afterwards with an insulating compound. The latter method is only applicable to units of small size, and its value is particularly apparent when used with transformers having a large number of turns of small wire, as the individual turns are cemented together and the whole winding is solidified, making a better heat dissipating body. With large transformers the coils are composed of a few turns of large wire and this point is of less importance.

Shape and Proportions. A transformer which has ideal proportions is one which requires the least amount of material for given conditions of loss, rating, etc. A little consideration will show that such a transformer will require that the length of mean turn of both iron and copper elements should be a mini-

mum for a given area of their sections. By their sections is meant the area of cross-section of the magnetic circuit and the area of cross-section through the windings. Thus, when the mean length of turns of each element is a minimum, a given number of turns of copper will have a minimum weight and resistance and the iron circuit would have a minimum amount of material. Such an ideal form of transformer would be one in which either the iron or copper assumed the shape of an annular ring, the other element assuming a circular cross-section surrounding the ring and completely filling its opening. The type would be core or shell, depending on whether the iron formed the central core, or formed the outer shell around the inner part. Because of considerations involving the material from which the magnetic circuit and windings are made, the question of heating, etc., it is not possible to use these ideal forms. Therefore a practical modification of one of these types of design must be selected. Upon analysis it is found that small high voltage transformers should be core type, and large low voltage transformers should be shell type. This is true for the following reasons: A shell type transformer has a short mean turn of iron, while a core type has a short mean turn of copper. There is a tendency to use the greater amount of the material having the shorter mean turn, because with a given amount of material, the part which has the shorter mean turn is the most effective in producing an element of large sectional area. The materials are economically disposed when with a given amount of iron and copper, the sectional area of each is a maximum. This is true because the output of a transformer is a maximum when the product of these areas is a maximum. With a shell type transformer, since the weight of copper is small, the sectional area is small and the space factor of the copper has a greeat effect upon the design; that is, the winding with a large percentage of insulation is at a disadvantage with the shell type. On the other hand, with a core type transformer, greater insulation values do not affect the design so markedly. The only means for judging as to the merits of the two types, concerning their relative economy for any particular case, is to make comparative designs.

Assume that it is required to design a power transformer of given rating for a minimum cost of material. It develops at once that there is a limit to the cheapness of a transformer for a given rating. This is due to the fact that for reasons of heating, the

copper cannot be operated beyond a certain density (measured in watts per pound), and the iron cannot be operated beyond a certain magnetic density because of saturation of the iron. The iron should run at not more than 10 000 to 12 000 lines per square centimeter, so as to keep below the knee of the saturation curve.

Thus the problem becomes one of designing a transformer for a minimum cost with fixed densities. If the scheme of insulation and ventilation has been selected, the space factor of the winding is approximately fixed. It can be shown that, with the rating, frequency, space factor and copper and magnetic densities fixed, the product of the area of the winding section and area of magnetic circuit section becomes fixed.*

It now remains to shape the transformer so that a minimum amount of material is required to produce this product of areas. Of course, the trial method may be used, but analytical methods have been worked out and are employed to advantage.

The premises in the above problem might have been to design a transformer for a minimum loss instead of a minimum cost, with the densities fixed. The two designs would be identical when the ratio of the costs per pound of iron and copper was equal to the ratio of the watts per pound in each.

Another phase of this general problem is of interest. Assuming that a design had been made for a minimum loss with fixed densities, suppose it were permitted to vary the densities up and down without danger of over-heating or over-saturation. Equation (1) may be rewritten as follows:—

$$W_1^{\frac{1}{1.7}} \times W_c^{\frac{1}{2}} \text{ is proportional to } \frac{P}{S_c \times A_1 \times A_c} = \text{a constant} \qquad (2)$$

Multiplying the above equation by a constant, we have—

$$(\text{Iron Loss})^{\frac{1}{1.7}} \times (\text{Copper Loss})^{\frac{1}{2}} = \text{a constant} \qquad (3)$$

This expression may be termed the transformer loss function, which means that in any transformer the figure for iron loss

*This may be expressed in an equation as follows:—

$$A_1 A_c \text{ is proportional to } \frac{P}{S_c W_1^{\frac{1}{1.7}} W_c^{\frac{1}{2}}} \qquad (1)$$

Where A_1 = Area of iron section; A_c = Area of copper section; P = output of transformer; S_c = Space factor; W_1 = Watts per pound of iron, and W_c = Watts per pound of copper.

raised to a certain constant power times the figure for copper loss raised to another constant power is equal to a constant. By the laws of maximum and minimum the relation between these losses which will make their sum a minimum may be found. This relation is as follows:—

$$\frac{\text{Iron loss}}{\text{Copper loss}} = \frac{2}{1.7} \qquad (4)$$

Therefore with a given transformer frame, this is the condition which must be satisfied when the sum of the losses is a minimum. The densities may be varied so as to effect a condition which will give the ratio of the losses as shown in equation (4), and thus make the sum of the losses a minimum. If the transformer had been designed as above, this condition would already have been established.

Equation (3) gives the law of the relation of the copper and iron losses in any transformer and shows how the iron loss may be decreased at the expense of the copper loss, or vice versa. For instance, if the iron loss of a transformer be reduced to 80 percent of its former value, the copper loss must go up to 130 percent. Actual economic designs do not in every case conform to all the proportions of the theoretically perfect design, since there are usually practical limitations which have to be considered.

There is another more complicated case, where it is desired to design a transformer whose losses are fixed, for a minimum cost of material. This is the condition involved in the design of distributing transformers. In the design of transformers of this class, as brought out above, the iron loss must be low in order to have a good all-day efficiency, and the copper loss must be low, to give the good regulation demanded by lighting service. Therefore the problem is not one of designing with fixed iron and copper densities, but the densities depend upon the losses. For example, if the losses are very low for a particular transformer, the iron and copper densities will be low, the iron and copper weights will be large and the cost of the transformer correspondingly high. This phase of the problem may also be worked out analytically and the cheapest transformer for the given conditions designed at the first trial.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

690—Outline Dimensions of Centrifugal Boiler Feed Pump—Will you kindly send me the outline dimensions of complete steam turbine driven, three-stage, 500 r.p.m. centrifugal boiler-feed pump, as shown on page 256 of the March, '11, number of the JOURNAL, in article "Steam Turbine Considerations." Does this turbine and pump set require as much steam to hold up water level on five boilers as on ten boilers; that is, does it take as much power to churn water with runner in case as to put water into boilers. C.E.H.

The outlined dimensions of the pump described are: Length, 9 ft. 3 in., width 3 ft. 8 in., heighth 4 ft. 3 in. Running at half load, the pump will take about 75 percent of full-load power. By referring to *Power and the Engineer, for* March 23rd, 1909, p. 535 (article on "Characteristics of the Turbine Pump," by Frederick Ray), information may be obtained regarding the operation of these pumps. E.D.D.

691—Allowable Variation in Width of Commutator Bars and Mica—If the space occupied by a given number of commutator bars, such, for example, as the total number of bars divided by the number of poles of the machine, be observed at various sections of a commutator, there will usually be found to be an appreciable variation. In a motor of, say, 100 to 200 hp. would a maximum variation of 0.01 to 0.02 inch per bar be allowable, assuming that the irregularities in adding up, would tend to compensate each other? C.W.F.

In building up a commutator, the mica, as well as the bars will vary in thickness and it would be commercially impossible to reject bars or mica varying, say, .001". On a motor of 100 to 200 hp, having, say, 200 bars, it may be found that 10 bars out of the 50 in a quadrant are 0.001" large while an equal amount may be 0.001" small, thus compensating somewhat for the error. The permissible amount of variation depends on the type of machine with which the commutator is used. If the commutating zone is rather wide; i. e., if the brushes may be shifted a certain amount without disturbing commutation, the amount in question may, of course, be larger than with, for example, a commutating-pole motor having a narrower neutral zone and a fixed position of the brushes for either direction of rotation. As a general rule, it may be stated that the variation in one quadrant should not be more than the thickness of the mica used between bars. C.W.S.

692—Amount of Skewing of Commutator Bars Permissible—Assuming an armature, with its coils in place and connected to the commutator bars, to be in place in the motor frame. If all irregularities are taken into account such as wearing of armature bearings, variation in thickness of commutator bars and mica, what may be considered as the maximum allowable angle between the center line of the armature bearings and the center line on any one commutator bar? C.W.F.

If reference is made to the amount of skewing of the commutator bars that is allowable for proper commutation, it may be stated that the commutator bars should be as near parallel to the axis of the motor shaft as possible. In building up a commutator, it is sometimes found that the mica compresses more on one side than the other, causing a skewing of the bars. Such com-

mutators should be taken apart and rebuilt. It is possible to build commutators without any appreciable skewing. C.W.S.

693—Coal Consumption of 85 Horse-power Engine and Effect of Altitude—What figures should be assumed for the probable coal consumption per indicated horse-power, in a steam plant employing an 85 hp, 70 r.p.m., simple non-condensing Corliss engine with a boiler pressure of 100 pounds per square inch, running at practically full load and supplied with steam from an ordinary fire tube boiler with natural draft and using a fair grade of steam coal, corresponding to Eureka, Clearfield Co., Pa? Is the performance of the engine or boiler affected by altitude, which in this case is between six and seven thousand feet above the sea? J.W.T.

An engine economy of 26.5 lbs. water per indicated horse-power hour may be assumed for a simple Corliss engine. This is practically correct when the small size of the engine, and, at the same time, the gain due to the lower back pressure of about three lbs. at this altitude, are taken into account. Although Clearfield coal is a high quality steam coal, it would not be advisable to estimate an evaporation of more than 6.5 lbs. of water per lb. of coal as fired, which results in a coal consumption of four lbs. of coal per indicated horse-power hour. An allowance should be made for auxiliary leakage and incidental losses of, say, ten per-cent, making the final quantity about 4.5 lbs. Obviously this is for full-load conditions and would increase for lower loads. If the boiler is to be kept under "stand-by" with full steam pressure for any lengthy period, the plant coal consumption will, of course, be greater. Although the engine will benefit from the diminished back pressure, at the higher altitude, probably no perceptible difference would be found in the boiler, but all pressure gauges should be carefully calibrated for these altitudes. E.D.D.

694—Single-Phase Generator with Fields Excited by Alternating-Current—Could a single-phase generator be made to generate a fluctuating direct-current by exciting the fields with alternating current? Assume for convenience a generator having revolving fields and the exciter to have an equal number of poles and direct-connected to the main generator so that the relative speeds would be fixed. Assume, also, that the zero value of the exciter e.m.f. would occur when the main field poles were midway between the armature coils. Now as the poles approach and pass under the armature coils a current will be induced in a certain direction. Then as the poles pass the armature coils again, the current and polarity will have reversed, thus maintaining a unidirectional current in the armature circuit. A north pole under one element of the winding will be a south pole under the next following element, but under any given element the polarity will always remain the same. If the above is possible, would the inductance of the fields, employing flux densities usual to alternator fields, interfere with the proper reversals of magnetism in the fields of the proposed direct-current generator? B.H.D.

This suggested arrangement for obtaining a direct-current type of generator is discussed in an article on "Some Phenomena of Single-Phase Magnetic Fields," in the JOURNAL, for September, 1906, p. 488, in which the fallacy of the scheme is pointed out. Instead of direct-current being obtained, the machine will in reality give single-phase alternating current of double frequency. B.G.L.

695—Preparing Storage Batteries for Shipment—I have a new storage battery of the Faure type. It has been charged about three times and now, however, owing to alteration in the plant it is not required, and it is desired to prepare the plates for shipment in a dry state so that they will not deteriorate and can again be placed in acid solution and charged on their arrival. H.A.B.

In general where a battery is to be put out of service the procedure should be as follows:—Charge the battery in the usual man-

ner until the specific gravity of the electrolyte of every cell has stopped rising over a period of one hour. If there are any low cells due to short-circuits or other causes, they should be put in condition before the charge is started, so that they will receive the full benefit. If the battery is of the vehicle type remove the elements from the jars, place on their sides with the plates vertical, slightly spread the plates apart at the bottom, withdraw the separators and pull the positive and negative groups apart. Play a gentle stream of water on them to wash off the electrolyte and then allow them to drain and dry. The positives when dry are ready to be packed. If the negatives in drying become hot enough to steam they should be again rinsed or sprinkled with clean water and then allowed to dry thoroughly. When dry, completely immerse the negative in electrolyte of about 1.275 specific gravity, and allow them to soak for three or four hours. After rinsing and drying they are ready to be put away. Rubber separators should be rinsed in water. Wood separators had better be thrown away and new specially treated wood separators furnished when the battery is reassembled. In case the battery is of the stationary type, charge the cells as in the case of the vehicle type, being sure that there are no low cells, siphon off the electrolyte, fill the cells with water and allow the plates to stand in them for 12 to 15 hours. The elements may then be removed and allowed to dry. Rubber or glass tube separators should be rinsed; wood separators if new should be packed and the bundle tied up with oilcloth so that they will not dry out, and in turn this bundle should be packed in a box of wet sawdust. The battery should then be packed for transportation in the same manner that it was packed when received. In reassembling, the battery should be treated as a new battery, and given the same initial charge as it received when it was first set up. See "Care and Maintenance of Storage Batteries," in the JOURNAL, for August, 1908, p. 466. L.H.F.

696—Calculating Horse-Power of Gas Engine—Please give rule for calculating horse-power of gas engine, using producer gas, when the diameter of cylinder, stroke, and speed are given. Will their power be in proportion to the volume of the cylinder (assuming sea level)? In what proportion do suction gas plants vary in power with the altitude at which they work? T.L.M.

The horse-power of gas engines on producer gas varies a great deal with the skill of the builder and with the quality of gas. With gas of 125 b.t.u. per cu. ft., such as is usual with anthracite suction type producers and ordinary engines, the power can be obtained by figuring on a mean effective pressure of 60 lbs. per sq. in. and a mechanical efficiency of 85 percent. With increasing altitude the indicated horse-power varies with the barometer, while the difference between indicated hp and brake hp is constant and is about 15 percent of that at sea level indicated hp. A.T.K.

697 — Book on Electric Smelting and Refining of Copper and Silver—Please give name of a good book containing complete information on the electric smelting and refining of copper and silver. What firms make apparatus for such work? E.M.A.

We would suggest Borchers "Electric Smelting and Refining" as the best book of which we know on electric smelting and refining of copper and silver. The price is $7.00. Numerous kinds of apparatus are required in the different processes of electric smelting and refining. We do not know of any one company that makes a specialty of supplying all of the desired apparatus; however, by referring to the advertising pages of various electrical, mining, and metallurgical periodicals information regarding various concerns may be obtained. J.M.M.

698 — Power-Factor of Induction Motor—Is the power-factor of an induction motor the same for all loads, and how is it figured? Can it be derived from the data on the name plate? C.E.B.

The power-factor varies at differ-

ent loads. It is usually greater at full load, and decreases with loads above and below approximately full load. It cannot be figured from the name plate. The power factor can be measured with sufficient accuracy for ordinary purposes, in lieu of a power-factor meter, by determining watts input per phase with a wattmeter, and the volts and ampere input for the same phase with a voltmeter and ammeter. Then power-factor equals watts ÷ (volts × amperes) = watts ÷ k.v.a.

699—Material for Repairing Electric Irons—*A*—Where can I obtain liquid enamel such as is used for electric irons? *b*—Is the high resistance wire used in these irons German silver? Where can it be obtained? *c*—How is the wire for the heating element wound and connected for alternating-current use? *d*—In repairing them I have tried French chalk and shellac for sealing the wires. J.A.C.

a—Suitable material can probably be obtained from any of the large potteries. By experimenting with various glazes, you could probably determine upon a proper mixture for the purpose in question.

b—No. Several of the steel companies manufacture an alloy useful for electric heating resistance.

c—A non-inductive winding should be used, *i.e.*, the conductor should be wound back and forth so that the current will have opposite directions in adjacent sections of the winding; or, the conductor may be wound in a coil and then flattened. *d*—The compound suggested for sealing the wires is not satisfactory for use inside the iron on account of the high temperature; the shellac would be driven off, leaving powdered chalk. E.E.F.

700—Adjustment of Tirrill Voltage Regulator—A Tirrill voltage regulator is operated in connection with a 125-volt, 30-kw exciter, direct-connected to a three-phase induction motor, to give an alternating-current generator voltage at no load of 2 300 volts, with 70 volts on the exciter. The regulator has given excellent service for the past year. However, it has given trouble lately at different times from pumping of voltage at normal load and when there are changes of load. Contact screw *19* (as per instruction book) has been examined and found to be securely tightened and properly adjusted. Levers 5 and 17 have been examined for friction at the points where core stems *23* and *24* are attached. In fact the regulator has been examined thoroughly for friction and loose contacts and the wiring has been examined for poor connections, but nothing has been found amiss. The dashpot has also been examined and all adjustments with the exception of the relay contacts are just as made at the factory when shipped. The relay contacts are kept true and adjusted at 1/32 inch. With 65 volts on the exciter the white line on gauge *37* does not come exactly in line with the underside of lever *5*. Would this cause any pumping? E.L.B.

From the information given it would seem that the only thing necessary would be to close the valve in the dashpot slightly, making the dashpot a little stiffer. This should be done carefully, however, so that it will not be made stiffer than is necessary. The dashpot adjusting screw might be marked and raised about one-fourth of a turn at a time until the right point is reached. The grade of oil used in the dashpot has a great deal to do with the operation; therefore the adjustment made at the factory may not hold good if some other kind of oil has been used. In regard to lever *5*, it may be stated that if springs *1*, *2* and *3* are adjusted properly in accordance with instruction book it would not make any material difference if the line on block No. 37 does not come exactly at the bottom of lever *5*. We would suggest that the exciter field rheostat be examined to see that it is adjusted in accordance with adjustment and sectionalizing of field rheostat (Page 12, Instruction Book No. 8 358). If there is not sufficient resistance included in the circuit by means of the exciter field rheostat, the dash pot may have to be adjusted too stiff for the proper operation of the regulator, or if it is free it may cause hunting. A.A.T.

WITH THE PUBLISHERS

With the present issue are included two supplements, one The Title Page and Table of Contents for 1911, and the other The Eight-Year Topical Index.

CIRCULATION STATEMENT

The total edition of THE ELECTRIC JOURNAL for the year 1911 was 148,500 copies, thus the average edition for the year was 12,375 copies per issue.

THE PUBLICATION COMMITTEE

Owing to the fact that Mr. Chas. F. Scott, of the Publication Committee of the JOURNAL has removed his place of residence from Pittsburgh to New Haven, Conn., where he now is in charge of the electrical engineering department of Sheffield Scientific School, Yale University, he has resigned from the Publication Committee and Mr. B. G. Lamme has been appointed as his successor. Mr. Lamme has been on the staff of the JOURNAL as associate editor since 1904 and hence is thoroughly in sympathy with the objects and aims of the JOURNAL. Mr. Scott is to be retained as one of the associate editors of the JOURNAL and it is hoped that he will be able to continue to be a regular contributor.

THE EIGHT-YEAR TOPICAL INDEX

The new topical index is a 48-page publication, covering all of the issues of the JOURNAL. In general, the article references are classified in this index according to their importance under four logical headings: "Generation," "Transformation," "Transmission" and "Utilization." In looking for articles on any desired subject it is necessary only to keep these main headings in mind. All articles which have been published on any one subject will be found classified under the proper topical headings. An outline key is given on page two to assist in the rapid and convenient use of the index. The saving in time and effort in locating references, which is secured by the use of this method of indexing, have gone far toward making the columns of the JOURNAL popular and valuable. References are also given throughout the index to answers in THE JOURNAL QUESTION BOX. Copies of the Topical Index will be supplied at 25 cents each.

VOLUME EIGHT

The volume for 1911 contains 1148 reading pages, as compared with 998 for 1910 and 772 for 1909, and thus is considerably larger than any previous volume. Copies of Volume VIII will be available after February 1st. Orders may be sent in at any time and will be filled in order of their receipt as soon as the volumes are received from our bindery. The old price of $4.00 per volume will still be in effect for the present, notwithstanding the continually increasing size.

Those wishing to have their copies bound should forward them at once with the Table of Contents and Index. The charge for binding is only $1.25. Missing copies of 1911 issues will be supplied at 25 cents each.

PERSONALS

Mr. Elbert L. Hyde, recently assistant examiner U. S. Patent office, Washington, D. C., has become associated with Frederick W. Winter, patent attorney, Oliver Building, Pittsburgh, Pa.

Mr. Reginald B. Benger, sales manager of the carbon brush department of the Morgan Crucible Company, of London, England, is at present making a business trip to the United States. His company is just starting an American branch factory in New York.

Mr. H. W. Smith, of the Milwaukee office of the Westinghouse Electric & Mfg. Company, has resigned to accept the position of electrical engineer of the Cleveland Construction Company. For the next few months his work will be principally at Michigan City, Indiana, adding equipment to the powerhouse of the Chicago, Lake Shore & South Bend Railroad.

Mr. C. E. Clewell, who has been for some time in immediate charge of shop and office lighting of the East Pittsburgh works of the Westinghouse Electric & Mfg. Company, has recently taken up work in connection with the illumination division of the detail and supply sales department.

The Iron Trade Review for December 21, 1911, contains a reprint of the article by Mr. A. G. Ahrens, entitled Power Requirements of a Steel Tube Mill from the JOURNAL for December.

PITTSBURGH SECTION—A. I. E. E.

The next meeting of the Pittsburgh Section of the American Institute of Electric Engineers, will be held on Tuesday, January 9th, in the auditorium on the 25th floor of the Oliver Building. The major paper on "Central Station Power in Coal Mines," will be presented by Mr. W. A. Thomas, commercial engineer of the Westinghouse Electric & Mfg. Company. In this paper will be discussed the requirements for power, the probable energy consumption per ton of coal mined, the load factor of typical small mining installations, the probable cost of power generated at the mine, large shaft hoists, the question of intermittent working of the mine due to market or labor conditions, and the general progress of power development and coal mining work. Mr. Thomas will give considerable data on costs, typical curves of load factors and results of tests. It is expected that this important subject will be discussed by a number of prominent operators and engineers, as the paper is of particular interest in the Pittsburgh district.

NEW BOOKS

"The Magnetic Circuit"—Vladimir Karapetoff, 283 pages, 64 illustrations. Published by McGraw-Hill Book Company, New York City. Price, $2.00.

This book, together with the companion book entitled "The Electric Circuit," is intended to give the theoretical elements necessary for the correct understanding of the performance of dynamo-electric machinery, transformers, transmission lines, etc. It contains also the essential numerical relations used in the predetermination of the performance and in the design of electrical machinery and apparatus. The whole treament is based upon a very few fundamental facts and assumptions. Professor Karapetoff maintains that every electric machine is a particular combination of electric and magnetic circuits, and that the performance of each must be based upon the fundamental electromagnetic relations rather than upon a separate "theory" established for each kind of machinery. The book is not intended for beginners. The treatment throughout is striking and, in many particulars, original. It is based directly upon the circuital relation, or interlinkage, between an electric current and the magnetic flux produced by it. This relation, and the law of induced electromotive force, are taken to be the fundamental phenomena of electromagnetism. The subject is treated entirely from the point of view of an electrical engineer, and the important relations and methods are illustrated by practical numerical problems, of which there are several hundred in the text.

"The Induction Motor"—Benj. F. Bailey; 225 pages, 120 illustrations. Published by the McGraw-Hill Book Company. Price, $2.50.

This is another addition to the already considerable list of books on the induction motor. It deals more with practical than theoretical considerations. A limited amount of space is devoted to explanation of the circle diagram. A chapter is devoted to starting devices. There are numerous illustrations of commercial apparatus. Considerable attention is given to design, with practical examples. The last two chapters are devoted to the single-phase induction motor. This book is essential a text-book for engineering students, especially for those who do not care to go deeply into the theoretical aspects of the subject.

"Electric Railway Engineering"—C. Francis Harding. 330 pages, 138 Illustrations. Published by McGraw-Hill Book Company, New York City. Price, $3.00.

While it is patent that this book is intended for use as a college text-book it will doubtless be of interest and value to others who may wish to gain general information on the subject. The book is well arranged for its purpose, beginning with the usual outline history of electric railway development. The principle topics discussed are: "Principles of Train Operation"; "Power Generation and Distribution"; "Equipment, Including Brake Construction, Rolling Stock, Motors, Control, Brakes, Car Houses, Electric Locomotives"; followed by a discussion of alternating versus direct-current traction and of electric traction on trunk lines. Evidently a book in which an attempt is made to cover such a wide field and can not go very thoroughly into the various devisions of the general subject.

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THE
ELECTRIC JOURNAL

Vol. IX FEBRUARY, 1912 No. 2

Extension of Electrification of New Haven Railroad

One of the most interesting announcements which has recently appeared, is that the New Haven Railroad Company has authorized the extension of its electrified system from Stamford to New Haven. When this extension is completed the electrified zone will extend from New York to New Haven and will include the electrification of the Harlem Branch with its extensive freight yards.

The present electrified portion may be considered a suburban proposition. The addition of the Harlem electrification modifies this condition somewhat by adding a large amount of freight service located within the suburban zone. The extension of the system to New Haven, together with the electrical operation of all passenger and freight service, transforms this into a true main line railway proposition.

This proposed extension is a marked tribute to the successful operation of the present New Haven electrical system and to the courage and enterprise of the railway company's engineers. In studying the features of the undertaking as a whole, the far-sightedness of the railroad company in making its plans becomes quickly apparent.

In the preliminary installation for example, the power house was located at Cos Cob, within four miles of one end of the electrified portion. The other end was at Woodlawn, eighteen miles distant, and the great bulk of the service was thus at one side of the power house and a considerable distance away. The electrification of the Harlem Branch, with its large yards, made the system appear still more lop-sided. The proposed extension of 42 miles in the opposite direction to New Haven and its yards places the power house more nearly at the central point of the service.

Again, with the extension of the system to New Haven the value of the use of 11 000 volts becomes at once apparent, since

it renders possible the use of the same trolley voltage all the way to New Haven, fed directly from the generator terminals. The length of overhead conductors tied to the Cos Cob generators will total over 500 miles.

A third point is the capacity of the electric locomotives which were installed for the New Haven service. Their one-hour rating was lower than certain other types of locomotives of practically equal weight, but against this their continuous rating was relatively high, and in this point they make a fine showing compared with other types. The locomotives were designed primarily for long hauls rather than for short hauls such as are required in terminal service alone. The extension to New Haven, with runs of several hours length, requires locomotives designed for high continuous rating and makes apparent the reason for the unusual design and rating of these engines.

There are several other features in this system which have shown at a disadvantage in the preliminary electrification, but which will now come into their own. All of these points had to be kept in mind by the Railway Company's and the manufacturers' engineers in making the original lay-out of the system. Had the engineers catered to current practice or given ear to all the criticism of the original plans, a preliminary electrification might have been installed along lines involving less risk, experiment and development, but also along lines which would not have allowed the eventual extension of the system without encountering greater difficulties than are incurred in the adopted system. Probably no large electrical undertaking has been planned with more foresight for future development and contingencies. B. G. LAMME

The Importance of Machine Tool Lighting

The illumination of factories, offices or apparatus may be effected in any of three ways, either by general (diffused), by individual (spot) lighting or by a combination of the two. While the first method is much to be preferred there is hardly an installation of any size where it can be employed exclusively. Recourse is therefore usually had to individual lighting as an accessory, and nearly all instances of successful interior illumination on a large scale may be said to consist of a combination of the two schemes with general lighting forming the major portion.

The subject of illumination has received such scant attention

from the public at large that the tremendous strides made in it within the past decade have been as yet but dimly appreciated. As a result, the designing of lighting systems in many new office and factory buildings still continues to be left to the architect who, being as a rule totally unfamiliar even with the fact that there is any science connected with illumination, leans upon so-called shop electricians for advice, with the natural consequence that the installations are in a majority of cases thoroughly bad. Further, where a lighting system has once been installed, the proposition is generally considered closed, never to be reopened as a whole, "patching" being instituted thereafter as occasion makes necessary, an individual lamp or a cluster being added or subtracted now and again, until even the original scheme, bad as it may have been, is entirely outclassed in this respect.

In any scheme of lighting there are certain fundamental requirements which must be fully met. These are:—Uniform illumination, proper intensity, proper quality, reliability, accessibility.

When these conditions have been fulfilled the following results, as pointed out in a previous editorial in the JOURNAL, will be obtained:—

Decrease in cost of operation and maintenance of the lighting system or increase in the quantity and quality of the lighting for the same cost.

Greater accuracy in workmanship with consequent lessening of defective work.

Increase in production with accompanying decrease in cost.

Reduced liability of accidents.

Lessening of eye-strain.

More cheerful surroundings.

Improvement in appearance and care of shop.

Easier supervision of the workmen.

The many types of lamps now available covering all ranges of units, from the lowest to the highest candle-power, enable a correct solution of practically every lighting problem to be made, so that little can longer be said in extenuation of poor lighting in any establishment; in fact, such a situation will soon be considered, and rightly, as one of the indications of bad business management.

In this issue of the JOURNAL, in the article by Mr. C. E. Clewell, a very commendable effort has been made to point out and to urge the advantages to be derived from an intelligent study of the prob-

lem, more particularly with reference to the lighting of machine tools. Throughout the article stress is laid upon general illumination in preference to individual lighting, as it is appreciated that the latter is more apt to be of a less permanently satisfactory nature than the former, although there are, of course, many instances where it is absolutely required.

There is little hesitation on the part of the average manufacturing concern in the spending of tremendous amounts of money for the purchase of machine tools where commensurate savings are likely to be effected. Such purchases are only made after supposedly the most thorough preliminary investigation in each instance, which is usually further reinforced by an actual demonstration involving an analysis of comparative expenses, time studies, etc., yet withall, the lighting of such tools on which so much depends, is almost invariably overlooked or else given but secondary consideration. The proper lighting of a tool should be looked upon as a part of the tool itself and, while costing far less in up-keep than many of the wearing parts, it is nevertheless just as important that the lighting be handled in exactly the same way and maintained at its highest efficiency.

C. B. AUEL

THE ELECTRICAL EQUIPMENT OF THE NEW YORK PUBLIC LIBRARY

M. C. TURPIN

THE New York Public Library on Fifth Avenue, between 40th and 42d street, being the most recently built among the great structures of its kind, in addition to its interest to the public in general, is of special interest to the engineering public, on account of the generating and heating equipment and the many electric and mechanical contrivances which have been installed to aid in the maintenance of the building and the care and handling of the books. The present library, which includes the Astor, Tilden and Lenox libraries, comprises over one and one-half million volumes, for which a total of over 400 000 running feet of shelving is provided. Seats and desk room are



FIG. 1—NEW YORK PUBLIC LIBRARY
Located on Fifth Avenue between 40th and 42nd Streets.

furnished for 708 persons in the main reading room and for about 1 750 persons in the entire building.

THE POWER PLANT

Electrical energy and steam heat are supplied from a central power plant located on the south side of the building with an entrance from 40th Street which is also convenient for the delivery of coal and the removal of ashes. The generators, two of 200 kw and two of 500 kw capacity at 250 volts direct current, are direct-connected to single cylinder non-condensing engines running at 150 and 100 r.p.m. respectively. One of the smaller units is located in each end of the engine room with two larger units

in the center, as shown in Fig. 2. They supply current for the lights throughout the building and for about 70 motors aggregating over 500 horse-power. The engine foundations are of concrete surrounded on the bottom and sides with a cushion of sand to prevent noise and vibration from being transmitted to the building. Steam is furnished at 135 pounds pressure from a battery of six 250 and two 240 horse-power boilers, exhaust steam being used for heating the building and the boiler feed water. A com-

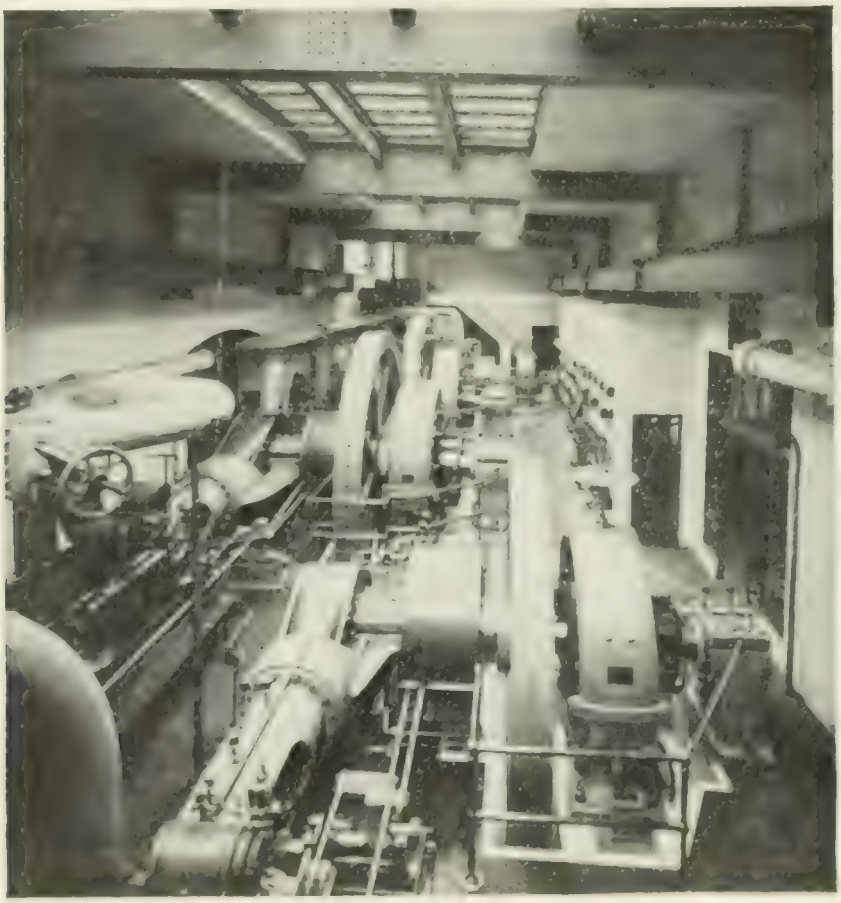


FIG. 2—ENGINE ROOM TAKEN FROM 42ND STREET SIDE.
Showing one of the 250 kw units in the foreground and switchboard at right.

bination coal and ash conveyor operated by a 10 horse-power motor lifts the coal into hoppers, weighs it and also removes the ashes. The sewage from the engine room is pumped to a well under the boiler room by a two horse-power motor-driven pump from which point it is removed to the city sewer. An 18 horse-power motor is used to drive a blower that brings air from the attic to the engine room, and forces the heated air to the boiler room thereby cooling the former and increasing the heat in the latter.

The engine room is partially illuminated by twelve-lamp incandescent clusters with porcelain reflectors mounted on the generators—a form of power house lighting quite prevalent in former years, but very little used of late. The remainder of the illumination is furnished by clusters mounted around the sky lights in the ceiling.

A storage battery of 141 cells is provided for taking care of the lighting from 10 o'clock at night until morning, and for emergency use in case of any accident to the generating equipment. The battery is controlled from the switchboard, a low reading voltmeter being so connected that the voltage of each of the 34 end cells can be read independently of the others. A one-half horse-power motor operates the end-cell switches. The battery is charged by a motor-generator set consisting of a 20 horse-power, 1 100 r.p.m., motor direct-connected to a 13 kilowatt shunt wound generator adjustable for voltages up to 110 volts. An exhaust fan driven by an eight horse-power motor, carries the acid fumes of the battery away to the roof through a lead duct.

Decidedly the most interesting feature in the engine room is the handsome white Italian marble switchboard which was built according to the specifications of the engineers for the building. This board consists of twelve panels, four for the control of the generators, one totalizing panel, one storage battery panel and the remaining six for the various power and lighting circuits in the building. Its height from the floor line is 12 feet 7 inches including a six-inch marble cornice that adds very greatly to the attractive appearance of the structure.

The generator panels Fig. 3 (on the right), are equipped with illuminated dial ammeters and voltmeters; rheostat mountings; equalizer switches, and small knife switches for controlling the cluster lights on the generators and the instrument lamps. A very complete system for voltmeter readings has been arranged by use of the differential meters and a 10-point voltmeter switch, so that the voltage of the bus-bar, incoming machine, distribution centers in the building, grounds, battery on charge and discharge, and individual end cells may be read from the generator section of the board.

Next to the generator panels is the recording meter panel on which are placed a graphic recording voltmeter and ammeter for registering the voltage and current of the system, two watthour-

meters, one for recording the energy delivered by the generators and one for that delivered by the storage battery. A two-pole, double-throw switch for transferring the power plant lighting load from the generators to the battery is also mounted thereon in a horizontal position.

The battery panel contains a double reading ammeter and differential voltmeter for indicating the current and voltage on charge and discharge of the battery; the control apparatus for the motor-generator charging set; a double-pole, double-throw switch for transferring the load from the generators to the battery and vice versa, and a portable voltmeter for reading the voltage of the end cells.

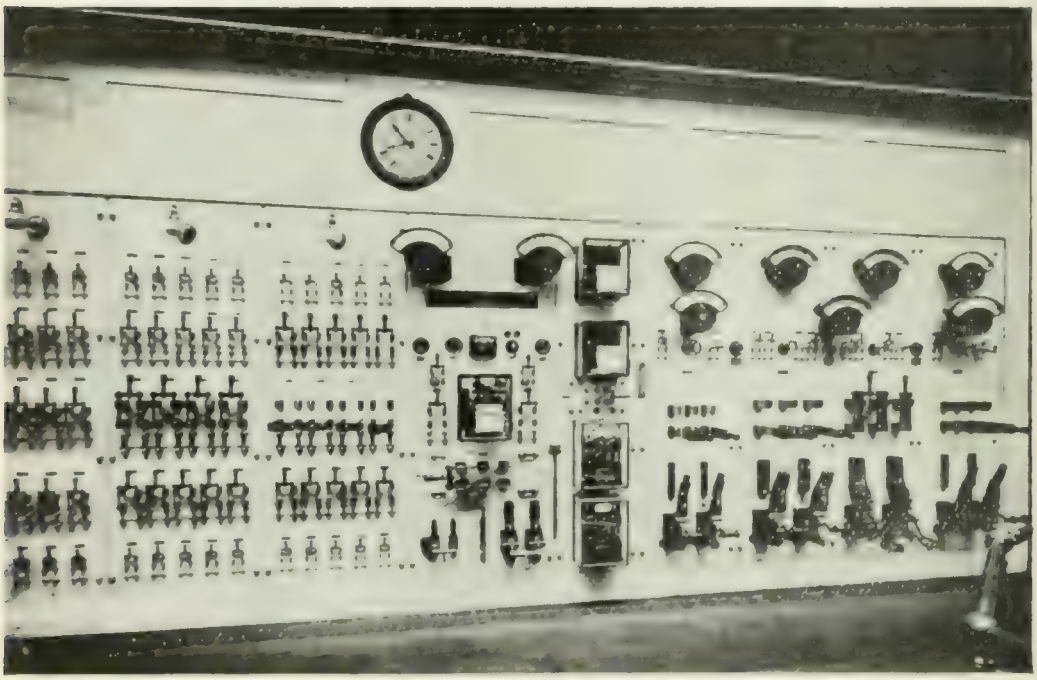


FIG. 3—WHITE ITALIAN MARBLE SWITCHBOARD, SHOWING GENERATOR, RECORDING AND BATTERY SECTIONS, AND THREE OF THE FEEDER SECTIONS

The feeder panels contain double-pole, single-throw knife switches and open link fuses of different capacities for controlling the various feeder circuits which run throughout the building. Under each fuse is placed a removable marble strip for protecting the marble of the main board from discoloration. The strips may easily be removed for cleaning. These panels are equipped with individual lights, while the other panels receive their light from the illuminated meter dials.

All connections on the rear of the board to the various switches are made by means of copper bars while those to the instruments are made with asbestos covered wire. The wiring at

the back of the board is done in a neat and careful manner, the switch studs being cut to varying lengths to suit the cables coming up through the floor. Copper rods covered with circular loom are used to connect the switch lugs to the feeders on the top of the board. The entire board is surmounted by 26-inch marble sections, in the center one of which is placed a large clock, and on the top of these sections is a six-inch marble cornice. The space between the rear of the board and the wall is enclosed by copper grill-work doors, which permit easy access but at the same time keep out unauthorized persons.

The feeder circuits between the switchboard and any lamp or motor are designed for a drop not to exceed five percent and, as some of them run from the plant to the extreme end of the building, a voltage of 250 was chosen in order to limit the copper necessary for these runs.

The electrical equipment for the power plant was provided by the Westinghouse Electric & Mfg. Company. An interesting feature is that it was furnished practically according to the same plans and specifications that were originally drawn by consulting engineers over fourteen years ago, when the work on the Library was first started.

THE HEATING AND VENTILATING SYSTEM.

The Paul system of exhaust steam heating is used, the radiators being placed along the outside walls of the rooms, and designed to take care of the radiation through the outside walls only. In addition a ventilating system is provided with capacity for changing the air in the rooms from two to six times per hour, depending on the location. Leather bindings of books are injured by dry air, so that it is necessary to provide a system of ventilation by means of which the humidity of the air is increased. Large screens are used through which the air is filtered, after which it passes through heaters supplied with exhaust steam from the engines and again through tanks of water or humidifiers, so as to get the proper degree of moisture. In this system, the air comes in at the top and is exhausted from the bottom of the room — contrary to the generally accepted theory of ventilation. Motors aggregating 105 horse-power are utilized for driving the various exhaust and ventilating fans.

VARIOUS MOTOR APPLICATIONS

There are numerous motor driven devices throughout the

building, which are of great assistance in the maintenance of the library.

All of the books are cleaned by the vacuum process. The machines are located in the engine room forming a central plant, and pipes run to various points throughout the building, one outlet being placed in every hall. Remembering the fact that there are a million and a half volumes to be cleaned, it may easily be realized what an enormous task is involved, especially in view of the fact that they are cleaned systematically every two or three months. By the old method of cleaning it was necessary to take each volume off the shelf individually, clean it with a duster or brush and re-



FIG. 4—METHOD OF CLEANING BOOKS AND SHELVES BY VACUUM PROCESS

place it. This is a laborious and very inefficient method because it is almost impossible to remove all the dust from a volume in this manner, and that which is removed simply becomes transferred to some other book or location. The method now in use is shown in Fig. 4. A squad of three men, consisting of a foreman and two workmen, is employed. The foreman supervises the work; one man places the books on the floor in groups of four or five at a time, and then replaces them while the remaining man operates the cleaner. This device consists of a circular, long haired brush attached to a hose, which is, in turn, attached to one of the outlets. The two operators hold the group of books on the floor in the same order in which they set on the shelves and then the brush is run

over the tops, and afterwards over the shelf from which they have been removed. By this system the books are cleaned rapidly, and the dust and dirt are actually removed from the books and room, instead of being transferred from one portion of the room to another. As an example of the advantages gained by this method, it may be noted that in cleaning the Stewart collection of 25 000 volumes, where such cleaning formerly took about a week, it now requires only about five hours.



FIG. 5—CLEANING FRONT STEPS OF LIBRARY
The scrubbing is done by the machine. The floor is then rinsed and dried by the men with brooms and mops.

The cleaning of the floors of the building is itself an enormous task and is effected every day. The cleaning is done by washing and scrubbing, no sweeping being permitted. An International floor machine is used, consisting of an electric motor mounted on a base or standard to which may be fastened any one of several attachments for grinding, scrubbing, refinishing or polishing the floors. A rotary motion is given to the attachment by means of the motor, resulting in an effective removal of the dirt and a good

polish. To clean all the steps of the building by the former hand method required the time of four or five men for a period of two and a half days, while by the modern method, shown in Fig. 5, it requires less labor and only about three hours time.

As will be noted from Fig. 6, the vacuum cleaners are also used to clean the interior wood work. The standard circular brush is used for general work and special ones are used for cleaning in crevices and intricate designs of the woodwork.

Another application of motor drive is that of the book lifts



FIG. 6—CLEANING WOOD AND PANEL WORK IN READING ROOM BY MEANS OF VACUUM PROCESS

which comprise a very elaborate system. These lifts are used for conveying the books from one to the other of the seven floors or levels of shelves. This arrangement is entirely automatic. An attendant on any floor, by pressing a button, may bring the car to the desired floor. Before the mechanism will operate, however, all the doors must be closed, or the lift will not start. They operate in a manner similar to the automatic elevators now in use in many private residences and apartment houses. Nine six horse-power motors are used to drive these elevators, each of which has a capacity of 250 pounds at a speed of 150 feet per minute.

Two passenger elevators, running from the basement to the third floor, have a capacity of 5 000 pounds at a minimum speed of 200 feet per minute, and 3 000 pounds at 250 feet per minute. These are each driven by a 40 horse-power motor, while a 15 horse-power motor is used to operate a freight elevator with a capacity of 3 000 pounds at 150 feet per minute. An elevator with a capacity of 3 000 pounds at 50 feet per minute between the engine room and the sidewalk, for delivering supplies, is operated by a 12 horse-power motor.

Among the numerous activities carried on by this institution, is a fully equipped printing plant and book bindery operated by thirteen motors aggregating 53 horse-power. The plant consists of four linotype machines, four bed presses, one folder, several cutting machines and a fully equipped book bindery. It is used to print catalogues, cards, directories, indexes and job work incident to the care of a library of such magnitude. A completely equipped machine shop is another important accessory, having nine one horse-power motors driving machine tools of various kinds. A two horse-power motor operates the pneumatic tube exhaust system, which is used to transmit orders, requests and receipts for books, and similar work. The system is similar to that used in large stores for transporting cash and order slips. In addition, there are two motor-generator sets for supplying low potential current for call bells, gongs, fire alarm, private telephones, intercommunicating telephones, book-conveyor and pneumatic tube-signal systems, and time clocks of which there are 75, all controlled by one master clock. A 30-volt motor-generator set is used to charge the storage batteries of two electric automobiles used in the transfer of books about the city and general haulage work of the library.

An idea of the extent of the plant may be had from the fact that a force of 95 employees is maintained for the operation and maintenance of the building alone — not including the library employees proper. The power plant is operated in three shifts by an engineer, fireman, oiler, coal passer, and two helpers.

MACHINE TOOL ILLUMINATION

C. E. CLEWELL

LIGHT is the term now commonly employed to indicate the cause, while illumination is used to indicate the effect produced by the lamp. This article sets forth a study of both cause and effect in their relation to the successful operation of machine tools at those portions of the day when artificial lighting facilities are required.

In a broad sense the most advantageous scheme of illumination in the shop is that wherein the source of light is separate from the machine. This insures a resulting illumination on the tool adequate both in quantity and direction under certain conditions to permit of the most rapid and accurate work. Many advantages commend this method;—the lamps are not in the way of the workmen; the surroundings, as well as the machine, can thus be properly illuminated; and the work is simplified on account of an absence of dark spots and marked shadows. Some cases, however, arise where over-head illumination will not give satisfactory results. Among the points which will be taken up, in the consideration of the satisfactory illumination of these special cases, will be the cost relations of machine tool operation, schemes found advantageous in mounting the lamps on the machines, and methods employed for concentrating the light at the point of operation.

ITEMS IN THE COST OF OPERATION*

Much development work has been conducted for the purpose of improving and perfecting the mechanical features of machine tools, methods of driving and accessories. Notwithstanding these improvements, one of the vital and essential items relating to the operation of these highly efficient machines is the man in charge. His efficiency is often the controlling element in the resulting product. It is this man-efficiency with which we are most concerned in a consideration of one of the elements which contributes to success or failure.

Up to the present time the illumination which is necessary to aid the employee in his work has been largely neglected in the development of machine tools, and seldom is there to be found a

*The following items as related to machine shops are adapted from an article by the author in the *American Machinist* under the title, "The Artificial Lighting of Machines."

machine tool where the lamp has been embodied as a part of the mechanism by the manufacturer. In most cases this item is left to the judgment of the user of the machine and has in the past been given but slight attention.

As indicating the economy of placing more than passing care on the lighting of these machines an actual instance is here cited. The maintenance and energy cost of certain individual lamps in a particular shop amounted to about 25 cents per month per lamp. The man whose work was influenced by one of these lamps during that part of the day when natural light was inadequate received as wages approximately $3.00 per day. The maintenance and energy cost of the lamp, amounting to about one cent per day was equal, therefore, to the wages for about two minutes per day. The losses due to a poor location of this lamp, or to the necessity of holding the lamp in the hand for certain portions of an operation, can hardly be estimated in minutes, since by defective work or by time wasted they may exceed the cost of an improved lamp many times over. This instance is given merely to indicate the importance and at the same time the economy of devoting considerable attention to the perfecting of devices for suitably mounting the lamps and for directing the light where needed.

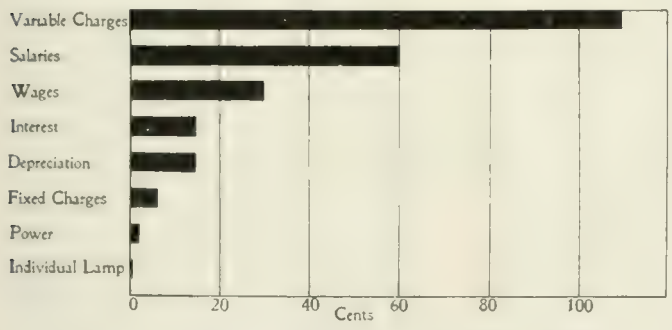


FIG. 1—CHART SHOWING HOURLY CHARGES AGAINST A TYPICAL MACHINE TOOL

TABLE I—AVERAGE CHARGES PER HOUR AGAINST A TYPICAL MACHINE TOOL.*

Variable charges	$1.100
Salaries	.600
Wages of operator	.300
Interest	.150
Depreciation	.150
Fixed charges	.060
Power, for motor drive	.020
Power, for individual lamp	.001
Total	$2.381

A study of Fig. 1 and Table I will show the relative charges

*These average values are taken from a table of charges in an article by Mr. A. G. Popcke, in the JOURNAL for Dec., 1909, p. 760.

which are made against a typical machine tool in a given shop, and furthermore that the lighting of the machine is one of the smallest items connected with the entire expense. The main point, however, is the fact that while the lighting is shown to be one of the smallest expense items, it is far more important in its relation to the successful operation of the machine than many of the other items involved in this expense chart. Light is therefore obviously a matter which should concern the shop manager, and this will doubtless be more the case in the future than in the past as the attitude changes



FIG. 2—MACHINE TOOL AS FORMERLY ILLUMINATED BY AN INDIVIDUAL LAMP

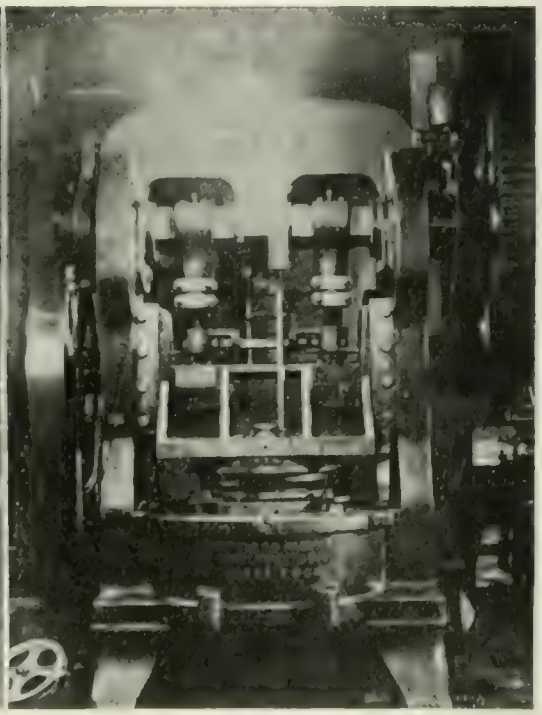


FIG. 3—THE SAME MACHINE AS SHOWN IN FIG. 2, ILLUMINATED BY A LAMP NEAR CEILING

so that the question is viewed as one of the important factors for promoting man-efficiency.

THE MOUNTING OF THE LAMP

The mounting of lamps for individual machine tool lighting may be divided into two classes;—first, where the lamps are mounted separate and apart from the machine; and second, where the lamps are attached directly to the machine.

It has been found by extensive experiment that in some cases the only unusual feature involved in properly lighting a piece of work in a machine is to provide more side light than is ordinarily afforded by lamps mounted at the ceiling or at the girder line. In certain cases, however, it has been found possible to eliminate the

necessity for individual lamps by using special reflectors on overhead lamps, which are capable of sufficiently increasing the side light. In Fig. 2, for example, a machine tool is shown as formerly illuminated by an individual lamp, which is now adequately illuminated by overhead lamps slightly lowered from the ceiling and provided with suitable reflectors, as shown by Fig. 3. This is exceedingly advantageous as the workman is thus saved the inconvenience of attending to a drop lamp which is constantly in his way and is liable to frequent breakage.

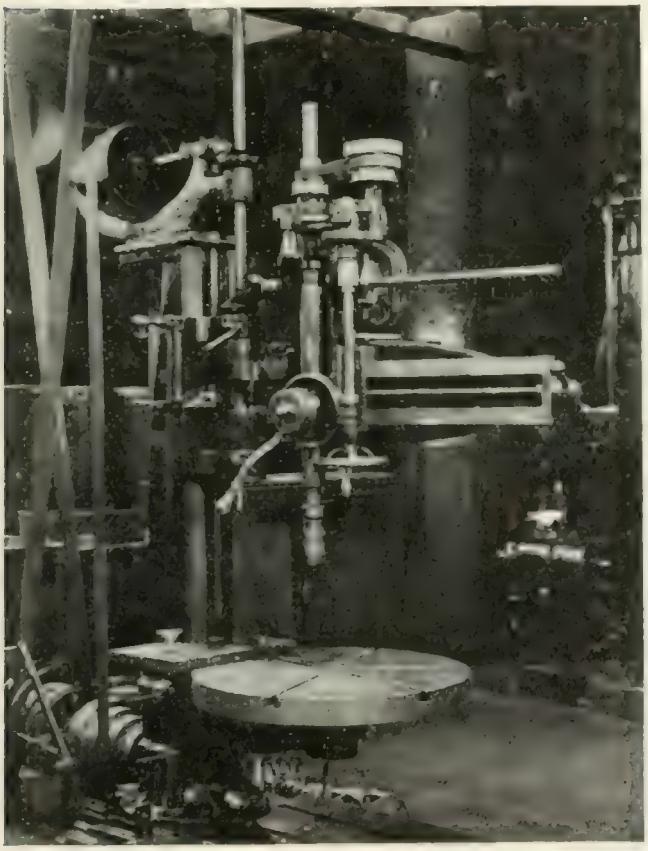


FIG. 4—MACHINE TOOL ADEQUATELY ILLUMINATED BY LOWERING THE OVERHEAD LAMPS

In one large shop, after careful observation of the relative floor space occupied by machine tools and the adjoining space used for storage of material, tools and the like, it was found that for every square foot occupied by the machine proper, approximately one square foot was used for the other purposes mentioned. This serves to indicate the relative advantages when a given lamp can be mounted somewhat above the machine tool, in that the illumination is thus utilized both on the tool and on the adjoining floor space. This advantage will be realized further when consideration is given to the necessity for using portions of the floor space immediately surrounding the machine tool when looking for materials, scales, or other accessories to the work in hand.

A machine tool is shown in Fig. 4 which has been lighted sufficiently by lowering lamps formerly mounted at the ceiling, to a height depending upon the dimensions of the machine, while Fig. 5 indicates a lathe which has been adequately lighted by the lamps at the ceiling, 13 feet above the floor, the lamps having been augmented in the matter of side light by special reflectors.

In the foregoing cases it will have been noted that the work in the main is looked at from above, so that upper surfaces of the work are the important portions requiring light. The foregoing instances show, in like manner, the very practical methods which can be used in mounting the lamps when they may be entirely separate from the machine itself.

In certain machine operations, however, the work must often be viewed not only from the side but also from below, and here the difficulties of an overhead mounting are experienced. In one factory location, as an example, milling machines were used exclusively.

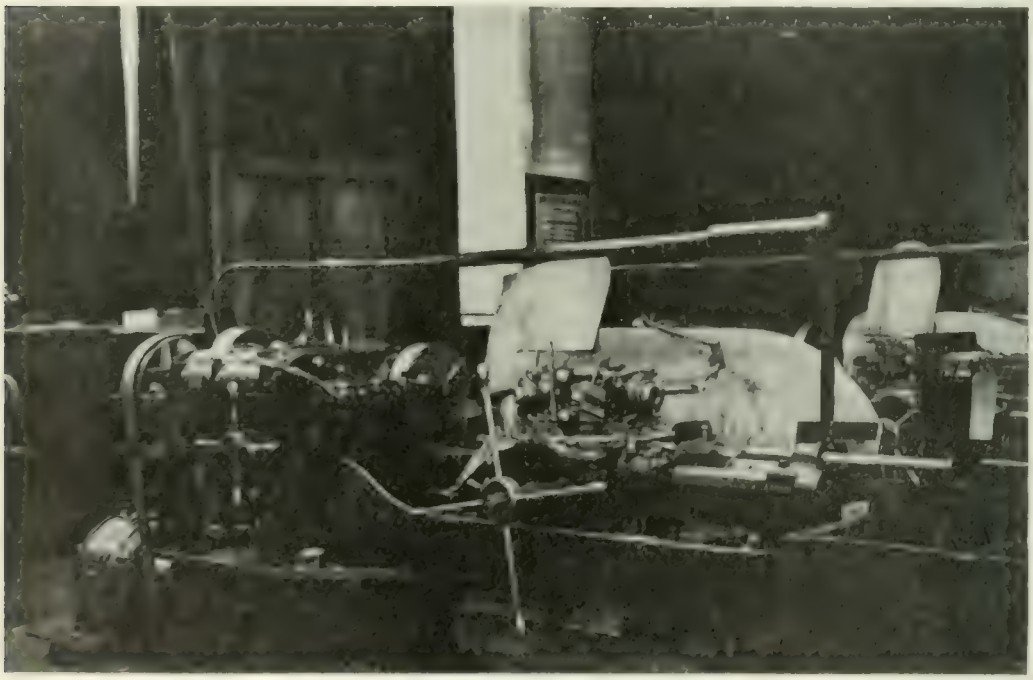


FIG. 5—LATHE ADEQUATELY ILLUMINATED BY LAMPS AT CEILING

The lamps in the background have been turned out to intensify in the photograph the effect of side light on the machine.

Much belting made overhead lighting difficult, but nevertheless an endeavor was made to solve the problem without the aid of individual lamps. The intensity of the illumination from the lamps overhead was increased from time to time until the number of units was much in excess of that required for bench work, and while sufficient for the top and in most cases for the side of the work, was not satisfactory for the under portions of the work in question. Finally a bracket composed of iron pipe sections was devised as indicated in Fig. 6, which permitted the lamp to be moved through a fairly large radius in all directions, and the workman was thus enabled to adjust the lamp to the point of importance.

Another case is that of large boring mills. One scheme which has proven quite satisfactory, where the machine is located relatively close to the wall of the building, is shown in Fig. 7. Here the lamp is suspended on a swinging arm attached to the wall directly behind the machine. Where, however, the machine is nearer the center of the shop, this swinging arm may be attached directly to the vertical portion of the machine. Still another scheme is shown in Fig. 8 where the work is so close to the operator that a device was made necessary whereby the lamp could be held firmly, close to the work and yet not in the way.

THE IMPORTANCE OF PROPERLY DIRECTING THE LIGHT

The suitable direction of the light on the work is by far the most important of the factors under consideration. Many workmen by their own ingenuity have devised methods of mounting lamps for their particular needs, some very crude, but none the less valuable. The feature of properly directing the light where required is of twofold importance; first, in the avoidance of the glare caused by looking directly into the lamp when no shade or reflector is provided, and second, in order to utilize the light where most needed.

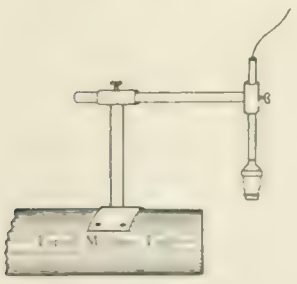


FIG. 6—SIMPLE BRACKET ATTACHED TO MACHINE AND USED WITH INDIVIDUAL LAMP

The distribution of light in an approximate manner when the lamp hangs suspended pendant without a shade or reflector is shown in Fig. 9. A reference to the tool which this lamp is supposed to light will show that practically all of the light from the lamp is wasted in directions which are not effective on the tool itself. Assuming that the workman stands to the left with his eyes about on a level with the lamp, it will be apparent that not only do the light rays fail in properly lighting the tool, but that a large portion falls directly in his eyes. It is a matter of common experience that to look directly into a lamp when attempting to view an object, produces a blinding effect which greatly reduces the efficiency of vision, and this is one of the most common blunders made in machine tool lighting at the present time.

Many workmen provide a shade of some kind so as to shield the light from the eyes, and one of the improvised shades of this kind is a cone formed from dark metal with which the lamp is surrounded. Such a metal cone tightly surrounding the lamp is shown in Fig. 10,

and it will be observed that, while the rays of light are shielded from the eyes, they are also rendered ineffective in lighting the tool.

A simple remedy for this condition of affairs is shown in Fig. 11. By the provision of a scientifically designed reflector, the rays of light are not only cut off from the eyes of the workman, but these same rays of light are reflected from the bright surface of the metal in such a way as to be directed to the tool, which is illuminated in a satisfactory manner. A photograph taken under artificial light, where the lamp is unprovided with a reflector is shown in Fig. 12, while Fig. 13 shows the same machine where the lamp has been equipped with a metal reflector designed to throw the light where needed.

OTHER ITEMS OF IMPORTANCE

Physical Size of Lamps—The size of an individual lamp has a bearing on its effectiveness in that a bulky lamp cannot be placed close to the tool when in operation. Some machines are so designed that it is imperative to have the lamp close to the point of operation. A small lamp, therefore, equipped with a highly efficient reflector of small size will be an advantage in such cases. It is also difficult to obtain the desired result in these particular instances with the lamp in a pendant position mounted at the ceiling. A fixture with an adjustable device mounted directly on the machine is generally the most desirable arrangement.

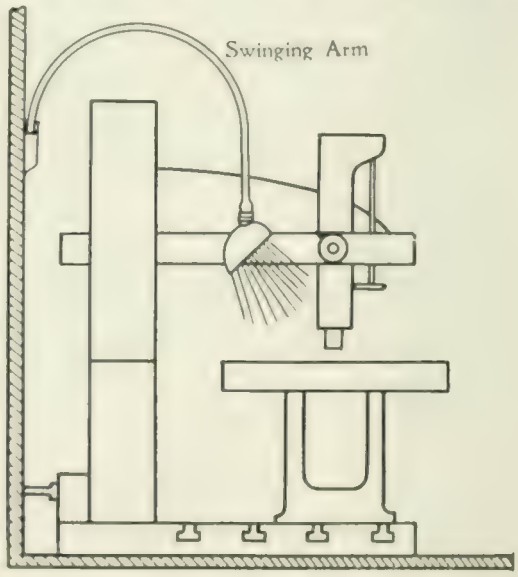


FIG. 7—SWINGING BRACKET ATTACHED TO WALL AND USED WITH LARGE MACHINES

Importance of General Illumination—In all that has been said with respect to the individual lighting of machines, reference should again be made as at the beginning, to the importance of providing some general illumination in addition to that provided by the lamp on the machine, and in like manner to the advantages of eliminating all individual lamps where possible.

Extension Lines—Nothing save a hint has been given regarding those cases where the work must occasionally be viewed from below.

Here the use of flexible extension lines is generally essential. It will often be found best to mount a few sockets over the machines on lamp cord attached to the ceiling, to which short flexible lines may be attached for occasional use. Where much belting exists and where the machines are close together this has some advantages over mounting wall receptacles on adjacent columns or walls, since in the latter case flexible cord will necessarily rest on the floor or on top of adjacent machines when the lamp is used for a machine somewhat remote from the column, and the wear and tear on the cord is thus increased.

The physical make-up of extension lines is important. In one large shop, the common form of extension line consisting of socket, wire guard for the lamp, handle, ordinary lamp cord and attachment plug, resulted in excessive maintenance due to the rough usage to which parts of the line were subjected. A study was made of the weak points of the old form of line and a new one devised of strong twin flexible cable and a specially constructed lamp guard with protected socket which prevents damage to both socket and lamp.

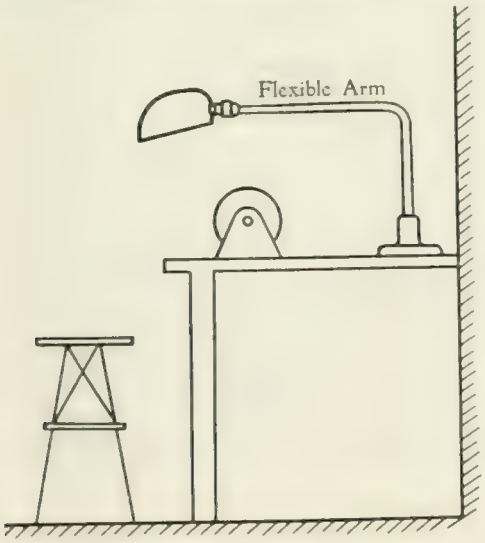


FIG. 8—FLEXIBLE ARM USED FOR SMALL WORK

Shadow Contrasts — Sometimes the workman depends largely on shadow contrast in his work. Die fitting, and certain assembly operations call for the exercise of this otherwise objectionable feature of the light, and a portable lamp in the workman's hand will likely be an actual advantage rather than a hindrance. This instance is cited to show that the establishment of a rule in a shop that no portable lamps are to be used may be a disadvantage to some workmen in special cases.

Candle-Power of Lamps—The candle-power of the lamps suitable for machine tools has not been touched on, largely because this is an item calling for the judgment of the man in charge of this division of the shop equipment. While lamps of small physical size are desirable for certain machines so as to permit of their being used close to the work, this should be considered from the standpoint of advantageous placement, rather than from the viewpoint of saving

electrical energy. As indicated on the chart at the beginning, the costs of lighting are so small in proportion to the importance of the light in its influence on the entire operation of the machine, that a reduction of energy by the use of smaller lamps should be considered only when satisfaction results by such a reduction. Looked at from the other side, the individual lamps should be made larger rather than smaller if this step is attended by an advantage to the workman.

Intensity of Illumination—The intensity of the illumination furnished by individual lamps mounted close to the machine usually exceeds that used where flat benches are concerned, simply because the lamp is much closer to the object. This may be an added advantage of the individual lamps due to the dark nature of most machine work. Particularly in the case of inspection where the detection of faulty material and workmanship requires local lamps, the intensity must often be excessive in comparison to ordinary working values. It should be especially remembered that illumination is in proportion to the light reflected from an object rather than the light which reaches it.



FIG. 9 FIG. 10 FIG. 11

Fig. 9—Incandescent lamp without shade or reflector.

Fig. 10—Incandescent lamp with improvised metal cone shade.

Fig. 11—Incandescent lamp equipped with a carefully designed metal reflector.

CONCLUSIONS

In conclusion it may be stated that *effectiveness* should be the object in the mounting of machine tool lamps and in suitably directing the light rays on the work. A study of each individual case is the only feasible and practical method of procedure when installing artificial lighting, making use, wherever possible, of the experience of others.

Many workmen already possess definite ideas similar to those embodied in this article. Co-operation, therefore, with the men themselves and a suggestion here and there throughout the shop, will do much to promote the intelligent use of a suitable equipment of individual lamps. In the case of those who either through ignorance or thoughtlessness have not conceived the idea that bare lamps are harmful to the eye when looked into, and the necessity of directing

the light to the work by the aid of reflectors, an installation of several such lamps in a shop section with instructions to those involved, will often start the right ideas among the men, and others in adjoining sections, recognizing the superiority of the improved lamps will be likely to request them even before they are provided. The spreading of intelligence among the workmen after this manner is important because cases are likely to exist where, even after lamps have been installed according to intelligent design, the meaning of the reflector, and the proper setting of the lamp may be so little understood that they may not be used to advantage.

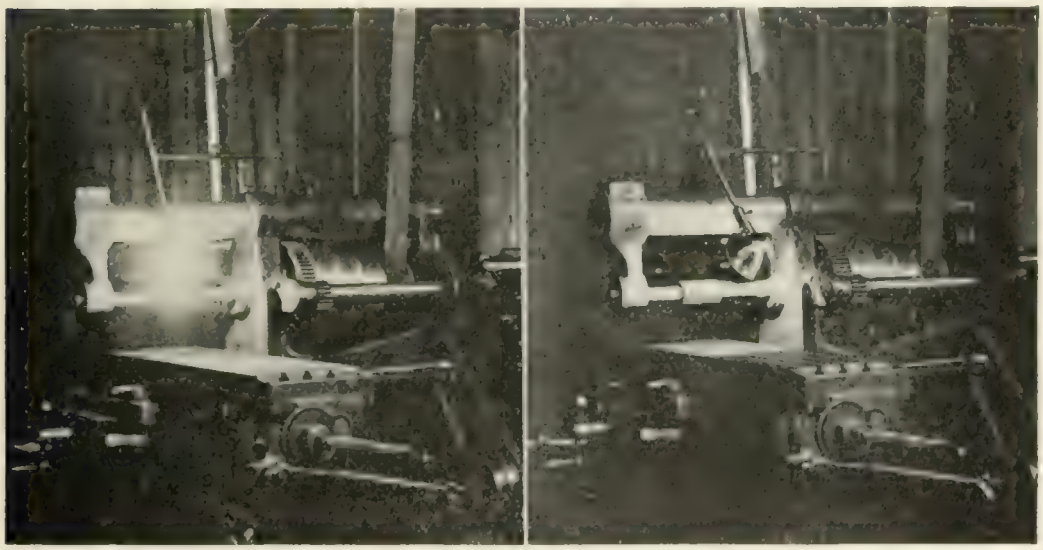


FIG. 12—MACHINE TOOL EQUIPPED WITH A BARE LAMP. NOTE THE GLARE

FIG. 13—SAME MACHINE WITH LAMP EQUIPPED WITH SCIENTIFICALLY DESIGNED METAL REFLECTOR

It is to be hoped that the growing attention to shop economy and improvements in the physical surroundings of the workmen will include among other features that of adequate and satisfactory illumination, and it is hardly going too far to remark that work along these lines is likely to result in an improved condition of the eyesight among employees in the industries, an item which in itself, not to mention the economy to the shop, is well worthy of a greater interest than has been accorded it in the past.

SINGLE-PHASE COMMUTATOR MOTORS

R. E. HELLMUND and E. W. P. SMITH

THE remarkable success of the single-phase commutator motor in railway work and the evidence of more or less confusion of ideas as to the principles of operation of the various types make pertinent a presentation of correlated facts regarding their design. A brief review of certain familiar features will be included incidentally because of their bearing on the subject.

PLAIN SERIES MOTOR

The fundamental principle of operation of the single-phase series motor is, as generally understood, the same as that of a direct-current series motor. The characteristics of the alternating-current series motor are therefore best demonstrated by a close comparison with the direct-current series motor. Considering the field magnetic circuit alone, it is evident that any standard direct current series motor could be operated on alternating current if it were not for the excessive heating caused by the heavy eddy current losses induced in the poles and yoke by the alternating magnetic flux due to the alternating current. To reduce these losses it is necessary to make the entire magnetic circuit of the alternating current series motor laminated, as is customary in every other type of alternating-current motor.

Considering the armature, the fluctuating nature of the main magnetic flux has another effect. At any given instant the brushes short-circuit one or more coils of the armature and, because of the fluctuating nature of the main flux, an electro-motive force will be induced in the coils short circuited by the brushes, which under certain conditions of operation leads to a heavy current and consequent excessive sparking. Therefore, to obtain satisfactory operation, this induced voltage must be made as small as possible by keeping at a relatively low value the flux interlinked with the short-circuited coils and the number of turns short- circuited by the brushes. Since the number of turns per coil cannot be reduced below one, and since the voltage induced in one turn by a flux such as is ordinarily used in larger direct-current machines is much too large to allow satisfactory operation, it would be necessary to reduce the flux in order to adapt the design of a direct-current machine for operation on alternating current. One way of reducing the flux interlinked with each

short-circuited coil, *i. e.*, the flux per pole, consists in splitting the total flux around the armature into a larger number of paths or poles than is customary in the design of a direct-current motor. While very effective in accomplishing the above purpose, as far as it can be carried out economically this method has certain limitations, in that the space around the commutator available for brush holders is limited. Therefore a second means for reducing the effective field flux per pole has to be resorted to, viz., that of reducing the effective magnetic densities. By reducing the effective densities around the armature, keeping the same armature ampere-turns, the torque of the motor is reduced. Therefore in order to bring the torque back to its former value the effective armature ampere-turns of the alternating-current motor must be increased, since in any machine the torque is proportional to armature ampere-turns and the field flux.



FIG. 1 FIG. 2 FIG. 3

Fig. 1—Main and cross fields as they exist in any commutating motor.

Fig. 2—Relation of cross field to main field in direct-current motor.

Fig. 3—Relation of cross, neutralizing, and main fields in an alternating-current motor.

Increased armature ampere-turns necessitate a larger armature diameter, while on the other hand low field densities require few field ampere-turns; hence a small winding space for the field coils, which is the reason for the short or stubby poles usually observed on alternating-current series motors. For a given frame, however, the short field poles and small field winding allow space for a somewhat larger armature diameter than in direct-current motors.

The decreasing of the effective main flux densities or the field ampere-turns, and the increasing of the armature-turns, however, lead to further complications which may be more fully considered. In the direct-current motor the resultant flux in the armature may be represented as made up of two components, *OA* and *OB*, Fig. 1, electrically at right angles to each other in space. The component *OA* represents the *cross field* due to the armature ampere-turns and

the component *OB* represents the *main field* due to the field ampere-turns. The main and armature fields may be assumed to have a fixed position relative to the field poles. This armature cross field is cut by the armature conductors which are short-circuited by the brushes. Consequently, as the armature rotates, the cross field induces an e. m. f. in the armature turns short-circuited, and this e. m. f. sets up currents in these turns. Therefore if the ampere-turns of the armature are made too large and consequently the cross field too strong more commutation difficulties present themselves. This is one reason why, in direct-current motors, the armature ampere-turns are kept small as compared with the field ampere-turns. It is especially the case in the direct-current machines without commutating poles that commutation considerations make it necessary to keep the ratio of armature ampere turns to field ampere-turns low. But even in direct current machines with commutating poles, employed to reduce the commutating difficulties by compensating the cross field within the zone of the short-circuited armature coils, it is not customary to make the ratio of armature ampere-turns to field ampere-turns large, for the following reasons: The cross field, which is neutralized only under the commutating poles, will exist over the rest of the armature circumference and will thus cause a very considerable distortion of the resultant field if the cross field is comparatively strong. A much distorted resultant field has several disadvantages. With a given effective value of the resultant field, the maximum densities, and therefore the armature core losses, increase with the distortion of the field. Furthermore, as the voltages induced in the armature coils are proportional to the magnetic densities at the armature circumference, a strongly distorted field having high magnetic densities at certain parts of the armature circumference will induce high maximum voltages between the commutator segments, which are liable to cause flash-overs, thereby impairing the reliability of operation. Since there is, moreover, little to be gained in the majority of direct-current designs in making the ratio of armature ampere-turns to field ampere-turns greater than certain values, the proportions in direct-current machines with commutating poles will be found to be similar to those indicated by the size of the vectors in Fig. 2, while in direct-current machines without commutating poles the ratio of armature ampere-turns to field ampere-turns is usually even smaller.

In the alternating-current motor, however, it has been shown that, for the reasons given above, the armature ampere-turns must

be relatively large as compared with the field ampere-turns, as illustrated in Fig. 3. Therefore, it is necessary to use some means other than that of a "stiff field" or low ratio of armature to field ampere-turns to prevent serious and destructive sparking, as well as field distortion due to a strong cross field. This cross field component can be reduced to zero by providing the machine with a compensating or auxiliary winding having such relation to the armature winding as to neutralize the armature ampere-turns. This compensating winding is arranged on the stationary part of the machine with its axis in line with the axis of the armature cross field, so that its magnetic effect is directly in opposition to that of the cross field, although it is connected electrically in series with the armature. In order to obtain the best results, *i. e.*, in order not only to compensate the armature effect as a whole, but at every part of the air-gap, it is customary to distribute the auxiliary winding over the pole faces so that it will correspond to the distribution of the armature winding (as indicated in Fig. 6 below).

It may be noted in this connection that in special cases and for the same purpose as outlined above, a winding of this kind has been applied to direct-current machines where either a high ratio of armature ampere-turns to field ampere-turns is of advantage with regard to design proportions, or where there is special danger of too high voltage between commutator segments, as in direct-current turbo-generators or machines for high voltages.

The use of the auxiliary winding made necessary by the use of a small main field, beside improving the commutation and the field form, serves, in the alternating-current motor, an exceedingly important purpose in relation to improving the power-factor. In an alternating-current motor any magnetizing current is objectionable in that it is a wattless current which causes a reduction in power-factor. It is necessary, of course, to magnetize the main field. The smaller this field the smaller will be the magnetizing effect required and hence the smaller the wattless current. Therefore, the weak field inherently necessary also assists in the production of a good power-factor.

In contrast with the magnetization of the main field, which, while lowering the power-factor, serves the necessary purpose of inducing the useful field, the magnetization of any other field like the cross field is absolutely useless and reduces the power-factor unnecessarily. Therefore, if there were no auxiliary winding the harmful cross field would exist, and would require another magnetiz-

ing force, which would mean an additional wattless current of considerable magnitude, since, as already noted the armature ampere-turns must be large in an alternating-current motor. Therefore, the compensating winding which opposes this field is also of great assistance in obtaining a high power-factor insofar as it eliminates this harmful and unnecessary field. The importance of the compensating winding as a means for improving the power-factor may be seen by reference to Figs. 4 and 5, which represent the vector dia-

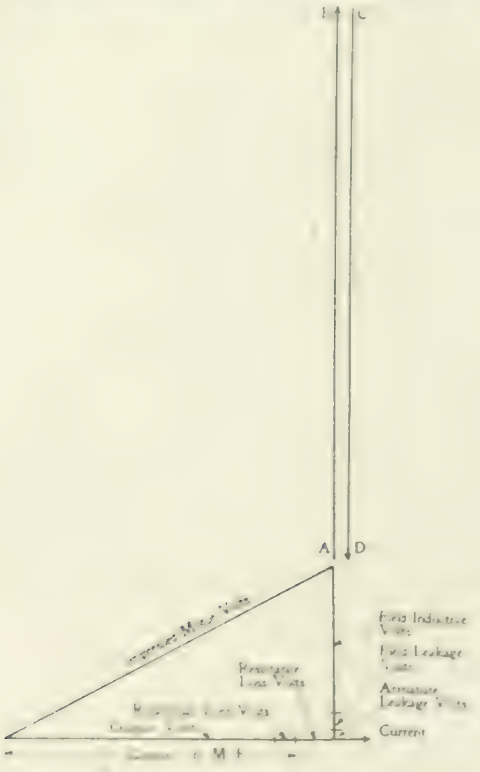


FIG. 4

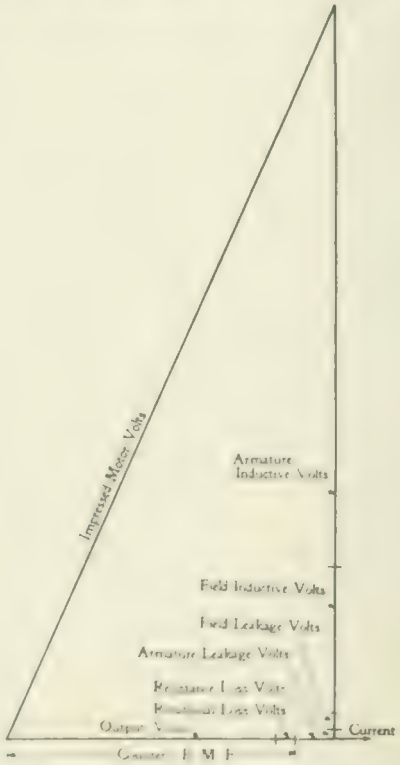


FIG. 5

Voltage diagrams of single-phase series motor with and without auxiliary windings.

Vector *AB* of Fig. 4 indicates the inductive voltage which would be induced if the cross or armature field existed without compensation. *CD* indicates the voltage which would exist if the field induced by the anxiliary winding existed alone. Thus, with both armature and auxiliary windings operative, no cross field exists.

grams of a single-phase series motor with and without compensating winding. If, as in these figures, the effect of the currents in the short-circuited coils are neglected—which is fully permissible for the present consideration—the diagrams are exceedingly simple. With the exception of the armature coils short-circuited by the brushes, all windings of the motor are connected in series and the construction of the whole motor diagram resolves itself into, first, a simple addition in one straight line of all counter-voltages caused by ohmic

resistance and by the rotation of the armature, the direction of the line being the same as that of the current vector, and second the addition of the reactive drops in a line at right angle to the current vector. In a motor having a compensating winding this leads to the relation indicated in Fig. 4. At any given speed and current, the counter-e.m.f., including rotational loss volts, resistance loss volts, field and armature leakage volts, and field inductive volts remain practically the same whether the compensating winding is in circuit or not. When a compensating winding is in circuit the inductive components are the field inductive volts and armature leakage volts. This gives a power-factor of about 90 percent, as shown in Fig. 4. If, however, the auxiliary winding is cut out, the armature inductive volts are added to the inductive component. This voltage is proportional to the cross field and gives a vector diagram as shown in Fig. 5, the power-factor being about 35 percent.

An important result of the use of the weak field and auxiliary winding is the reduction in the iron loss due to the alternating character of the current, since with the good field form obtained the densities are uniform and because of the moderate densities the losses are low.

Another difference between an alternating-current and direct-current structure is that the commutator of the alternating-current motor usually is larger in diameter, wider and also has more commutator segments than that of the direct-current motor, and for the following reasons:

In many direct-current designs it is perfectly admissible to have several turns between commutator segments. But as has been shown above, the voltage between segments must be reduced to a low value in the alternating-current motor, and therefore all but very small motors use only one turn between segments. The number of turns is therefore the same as the number of segments.

As the total voltage is proportional to the total number of turns in the armature, in order to avoid too small a total voltage, it is customary to make the commutator as large as is otherwise permissible and put in as many segments as the size of the commutator permits. In spite of this, the voltage of the single-phase railway motor is usually relatively low compared with the direct-current motor, as the limit is obviously one turn per segment. The current per brush arm is consequently relatively large and this in turn necessitates larger contact surface for the brushes and a longer commutator.

It may be mentioned further, that in many cases the air-gap of

single-phase motors is found to be smaller than in direct-current motors (especially in those without commutating poles where the air-gap is frequently made rather large for purely electrical reasons). These reasons are directly related to previous considerations. It was pointed out that a large field distortion is undesirable. Now a small air-gap reduces the field ampere turns required for a given flux density and consequently increases the ratio of armature ampere-turns to field ampere-turns, which in turn means increased field distortion in a direct-current machine. In the alternating-current motor where the field distortion is made impossible by the auxiliary winding this consideration does not enter, and since on the other hand a small air-gap will reduce the magnetizing effect re-

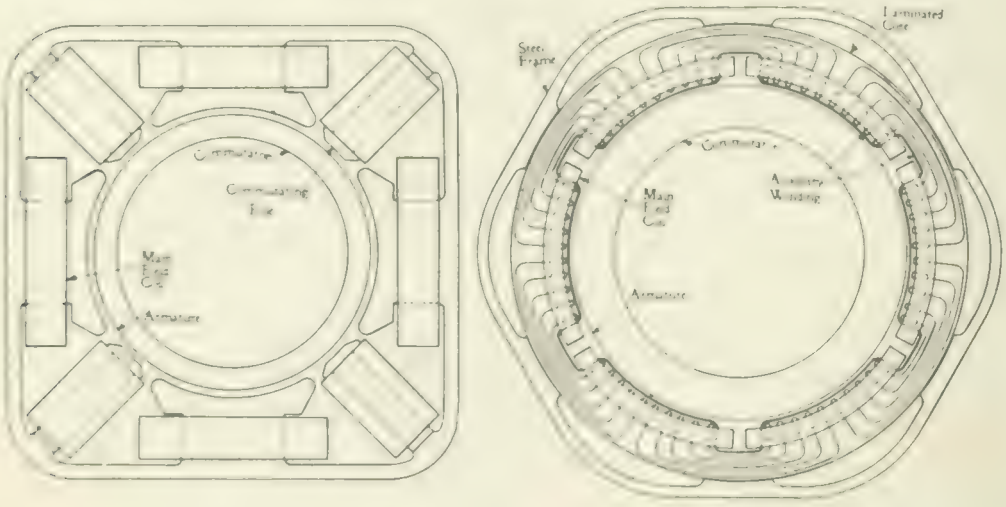


FIG. 6 FIG. 7

Schematic cross-sections of direct and alternating-current railway motors of corresponding ratings showing relative detail and over all dimensions.

quired and therefore be beneficial to the power-factor, it is evident that in the design of alternating-current motors the air-gap will always be made as small as mechanical considerations permit.

The differences in design requirements so far given explain the structural differences between alternating and direct-current motors. To summarize, these are:

1. The laminated core of the alternating-current motor.

2. The comparatively large number of poles of the alternating-current motor.

3. The use of a distributed auxiliary winding on the alternating-current motor in addition to the main field winding.

4. The larger armature diameter as compared with that of a direct-current armature.

5. The short and stubby poles made possible by the small number of field ampere-turns on the alternating-current motor.

6. The large and wide commutator of the alternating-current motor and the larger number of segments as compared with direct-current machines.

7. Small air gap.

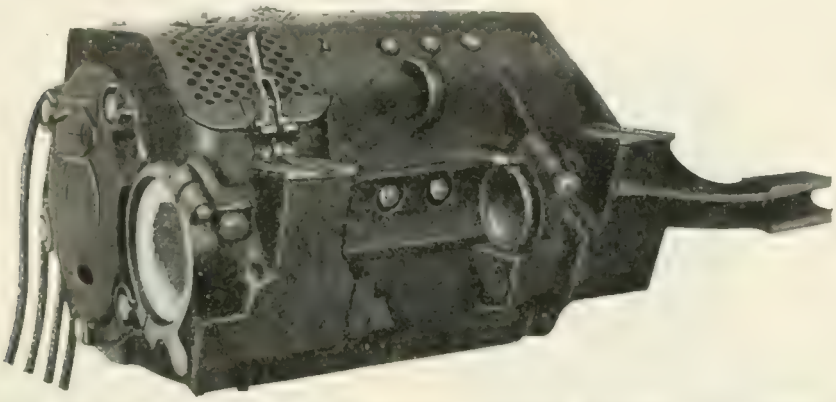


FIG. 8—COMPLETE DIRECT-CURRENT MOTOR SHOWN IN CROSS-SECTION IN FIG. 6

Some of these differences, their relative importance, and combined effect upon the size of the motor are shown in Figs. 6, 7, 8, 9, 10 and 11. Figs. 6 and 7 show the relative sizes of a 200 horse-power, 600 volt, direct-current railway motor and those of a 200 horse-power, 15 cycle, alternating-current railway motor, both for approximately the same speed. These illustrations show that, while

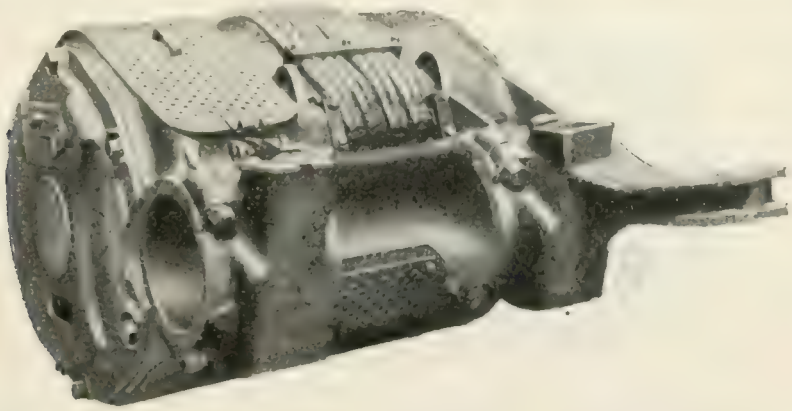


FIG. 9—COMPLETE ALTERNATING-CURRENT MOTOR SHOWN IN CROSS-SECTION IN FIG. 7

the armature of the alternating-current motor is larger than that of the direct-current motor, this difference is largely counterbalanced by the shorter poles in the alternating-current motor. Therefore the outside diameter of the stator core of both motors is practically the same. The overall dimension outside of the frame of the alternating-current motor is, however, slightly larger than that of the

direct-current motor; this is due to the fact that in the direct-current motor the stator core iron serves as the frame, while the laminated core of the alternating-current stator makes it necessary in railway work to build a substantial steel frame around the laminations. The overall dimensions of the two motors along the shaft are practically the same. While the alternating-current motor has a somewhat wider commutator, its extra length is counterbalanced by the fact

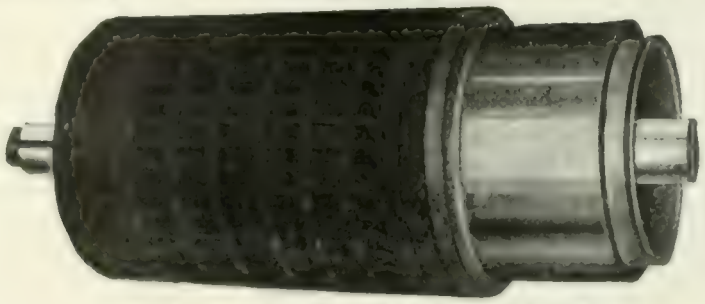


FIG. 10—DIRECT-CURRENT ARMATURE
For motor shown in Figs. 6 and 8

that the motor has more poles, which leads to shorter extensions of the armature coils outside of the core. The weight of the direct-current motor is 5 000 pounds; that of the alternating-current motor 6 000 pounds; a considerable part of this difference is represented by the difference in the frames, as described. Since both of the above motors represent modern designs intended for similar service, their figures may be considered as representative and it may therefore be stated that a 15 cycle alternating-current series motor is 15 to 25 per-

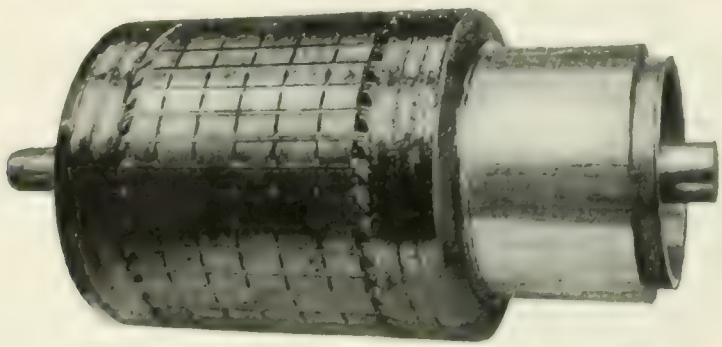


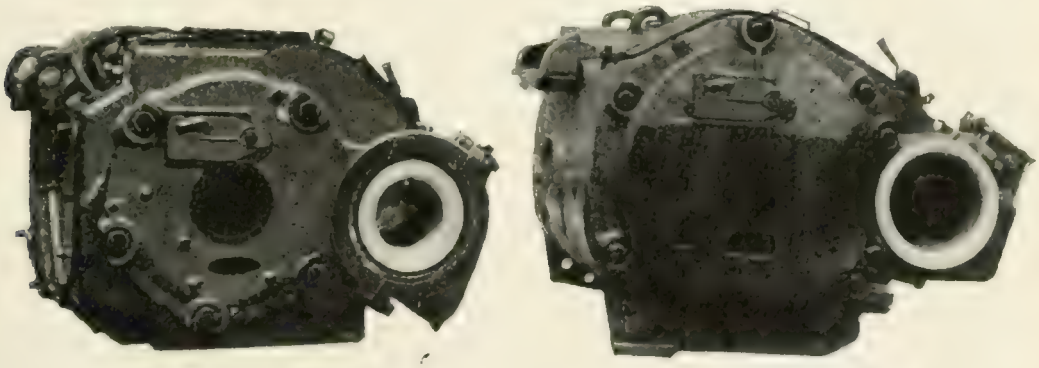
FIG. 11—ALTERNATING-CURRENT ARMATURE
For motor shown in Figs. 7 and 9.

cent heavier than a corresponding direct-current motor. For 25 cycle service, the alternating-current motor cited above is good for about 170 horse-power only. In general a 25 cycle alternating-current motor will be 25 to 45 percent larger than a corresponding direct-current motor, or 5 to 15 percent heavier than the corresponding 15 cycle alternating-current motor.

The points brought out in the preceding are further illustrated

by Figs. 8 and 9, which show the two motors complete, both to the same scale; also by Figs. 10 and 11, which show the two armatures. While the above comparative figures may be considered as representative, it should not be inferred that different figures will not be found in practice caused by difference in mechanical construction, choice of the ratio of armature width to diameter and a large number of other possible variations in design.

The previous comparisons are based on standard 500-600 volt direct-current railway motors and 15 and 25 cycle single-phase railway motors. Because of the recent advent of the 1200 and 1500 volt systems and their application to interurban service, a few figures showing the relative proportions of motors for these and the single-phase system may be mentioned.



Direct-Current Motor Alternating-Current Motor

FIG. 12—VIEW OF MOTORS OF CORRESPONDING RATINGS FOR 1500 VOLT DIRECT-CURRENT SYSTEMS AND 15 CYCLE ALTERNATING-CURRENT RAILWAY SYSTEMS

Compared with the motors for the high voltage direct-current systems, the single-phase motor is more nearly on an equal footing. This equality is due largely to the increase in weight due to the insulation construction required with the higher operating voltages of the direct-current motors. This is quite an important item, as may be judged from the statement that, in certain cases the 25 cycle motor is only 5 to 15 percent heavier than a direct-current motor for the high voltage system, and the 15 cycle motor is of approximately the same weight as the direct-current motor. The latter two may be compared by reference to Fig. 12. These comparisons merely indicate the relations toward which alternating and direct-current motor designs are tending.

THE OPERATION OF MERCURY ARC RECTIFIERS

Q. A. BRACKETT

VERY little has been published on the subject of mercury rectifier outfits which is of practical benefit to the users of this type of apparatus. This article has been written in an endeavor, in some measure, to supply this lack, and does not attempt to give a discussion of the theory of operation. Some elementary description, however, of the manner in which a rectifier bulb operates is necessary in order to make what follows plain to those who do not happen to be familiar with this subject.

An ordinary type of rectifier bulb is shown in Fig. 1, consisting of two side chambers in which are the so-called anodes, or positive electrodes, usually of graphite, two lower and adjacent pockets containing mercury known as the cathode and the supplementary or starting anode, and above them a cooling chamber in which the hot vapor condenses and then runs down into the mercury pools. The bulb after being assembled, as shown above, is exhausted to a very high degree of vacuum and then sealed. Its value as a rectifier depends on the fact that current can pass through the vapor in one direction only, namely from either anode to the cathode, and only in that direction when a hot spark has been caused to occur at the surface of the cathode of such polarity as to make the mercury negative. This is usually accomplished by applying a difference of potential to the two *mercury* electrodes and then tilting the bulb till the two pools flow together. Then when the bulb tilts back and the mercury pools break apart a spark occurs between them. If this spark is of such polarity as to make the mercury of the cathode negative and if at the same time a difference of potential exists between the anodes and the mercury, an arc will start from that anode which is positive to the cathode.



FIG. 1—30 AMPERE RECTIFIER BULB

The usual practice is to use an anto-transformer, the two ends of which are connected to the anodes of the bulb while the cathode is connected through the load to the middle or neutral point of the transformer. The action is then as follows:—For any given half wave the current flows from the positive end of the transformer to

one of the anodes, thence through the vapor to the mercury cathode and out through the load to the middle point of the transformer. The next half wave no current flows from the anode previously in use, but the other anode in turn delivers current to the cathode whence it flows out through the load in the same direction as before. If, however, the current in the first anode ceased to flow the moment the other anode started up the arc would go out. Therefore a certain amount of energy is stored in a magnetic field which by giving up its energy as the current falls prolongs the current through any given anode until the second has started up. This is spoken of as sustaining the arc, and at first was accomplished by introducing a choke coil in the direct-current circuit in series with the load. Now, however, sustaining is usually accomplished by introducing magnetic leakage in the transformer itself by means of a middle section instead of by a coil in the direct-current circuit. If no sustaining effect were present the rectified current would simply be a series of half waves. The sustaining action tends to fill in the hollows between waves and causes the rectified current to take the shape of a pure direct current with an alternating current superimposed upon it. The greater the sustaining effect the smaller the "ripple" or alternating current component and the smoother the direct current wave becomes.*

BATTERY CHARGING.

Where a rectifier is used for battery charging it is usually desirable for the outfit to have a bad regulation curve in order that it may carry through the charge from beginning to end without readjustment. That is, the outfit should be capable of rising in direct-current voltage the same amount that the battery does during charge without allowing the current to fall to the point where the arc goes out. This is usually accomplished by connecting a choke coil in series with the primary line leading to the transformer, the air-gap of which is adjusted to give the regulation desired.

Several methods of creating the initial spark at the surface of the mercury are available, the simplest of which is to connect a resistance from one of the anodes to the supplementary or smaller mercury electrode, of such value as to let a few amperes flow when the bulb is tilted and the pools run together. An ordinary incandescent lamp can sometimes be used for this in an emergency.

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*For more detailed description, see articles by Mr. R. P. Jackson in the Journal for May, 1909, p. 264, and Mr. Y. Sakai, in the Journal for March, 1910, p. 216.

A rectifier bulb is usually started by tilting. When first starting up an outfit for a charge this can be done perfectly well by hand, but if the outfit is liable to stop for any reason before the end of the charge while the operator is away, it is highly desirable to have an automatic starting device. The slightly greater cost will be more than offset by the time lost and the inconvenience resulting from the occasional finding of batteries only partially charged.

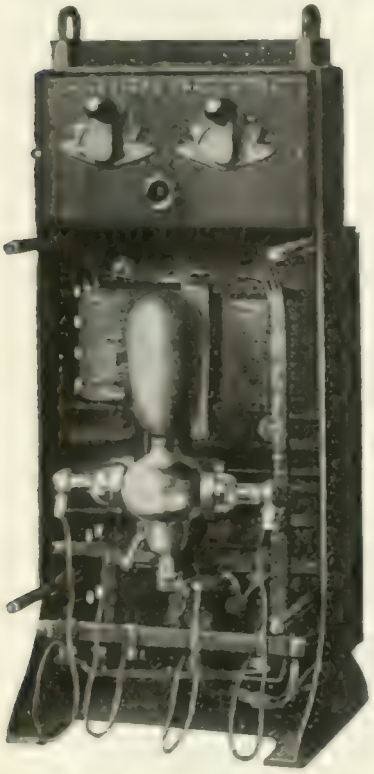


FIG. 2—AUTOMATIC STARTING, 30 AMPERE RECTIFIER
Front view with cover removed.

Such an automatic starting device consists of an alternating-current magnet that causes the bulb to tilt and is supplied with current either from the line through a resistance or from a small transformer. When the mercury pools come together they short-circuit the magnet. This allows the bulb to tilt back and break the current through the mercury pools, thus securing the desired spark at the mercury surface. If the main arc then starts up a relay cuts out the tilting circuit. If the main arc does not start at once the bulb tilts again and continues to do so until the main arc does start.

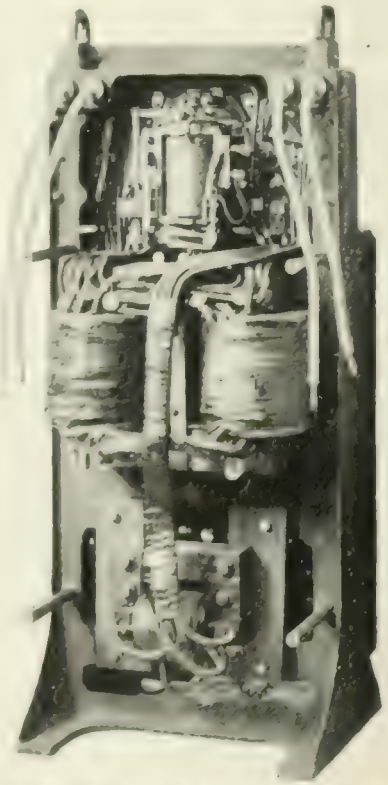


FIG. 3—AUTOMATIC STARTING, 30 AMPERE RECTIFIER
Rear view with cover removed, showing transformer, reactance, and relay circuit breaker.

Battery-charging rectifiers are most widely used in connection with electric automobiles. As many different numbers of cells are used in the various makes of cars it is necessary that a rectifier have facilities whereby it can be easily and efficiently adapted to charging any number of cells, within certain standard limits. This is usually accomplished by bringing out taps from the transformer or the primary reactance coil or both

to one or more dial switches so that those taps can be used that most nearly suit the number of cells to be charged. These dial switches are equipped with "preventive resistances" so that the arc does not go out and have to be restarted in passing from point to point, and the contacts themselves are saved from burning. These resistances are only in circuit while passing from one dial point to the next and will burn out if left in circuit for any length of time. For this reason the dial switches are made with well-defined notches so that they are certain to be left in the proper positions.

Front and rear views of thirty ampere automatic starting rectifiers are shown in Figs. 2 and 3, while Fig. 4 shows the wiring diagram of a 110 volt outfit. This outfit is designed for charging lead storage batteries, such as are commonly used in electric auto-

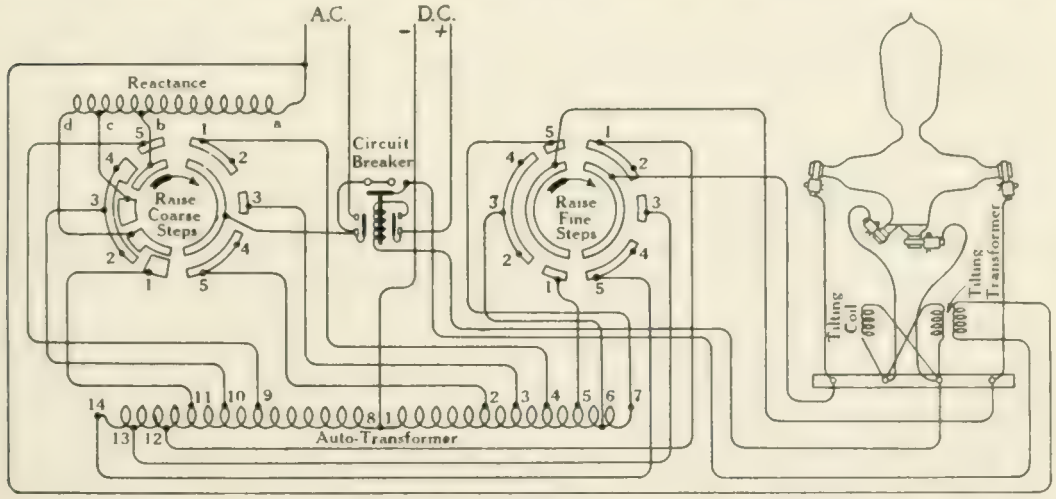


FIG. 4—WIRING DIAGRAM OF SELF-STARTING, 30 AMPERE RECTIFIER FOR 110 VOLTS ALTERNATING CURRENT, AND 20 TO 44 CELLS OF LEAD BATTERY

mobiles and is made in two sizes, one for charging from 10 to 24 cells and one for from 20 to 44 cells. Each size is made for two different line voltages, namely 110 and 220 volts, and ordinarily for 60 cycles. These outfits are entirely self-contained in one unit and can be moved about as desired. The bulb and all working parts are enclosed and thus protected from mechanical injury. They are equipped with an automatic tilting mechanism and thus are self-restarting in case the arc happens to stop during charge. This tilting mechanism is controlled by a relay, mounted on the back of the panel, which also acts as a circuit breaker and opens both the alternating and direct-current circuits in case of excessive direct-current. Two five-point dial switches are provided, connected to different transformer and reactance taps, thus providing 25 possible points of

adjustment to suit different numbers of cells. One dial gives variation of voltage by large steps while the other dial gives small steps for obtaining intermediate values. An auto-transformer is used, with a reactance coil connected in series with the primary and adjusted to give the correct slope to the regulation curve of the outfit.

Each outfit is so adjusted that if the dials are set according to the number of cells being charged and the line voltage, the rectifier will deliver a direct current of about 30 amperes at a voltage of 2.15 times the number of cells, and a current of about five or six amperes if the voltage rises to 2.55 volts per cell. These values of volts per cell represent the voltage of an ordinary lead cell under the two conditions of complete discharge and full charge respectively. When the voltage has risen to 2.55 per cell and the current has fallen to five or six amperers the arc will no longer sustain itself and will go out, automatically terminating the charge. This feature is used successfully by many operators as a means whereby they can start their charging at night and leave the batteries wihout attendance, relying on this characteristic of stopping automatically when the charge is complete. The adjustment of the outfit definitely assures that, if the direct-current voltage rises to 2.55 times the number of cells specified for the dial setting in use, and the line voltage remains reasonably constant, the current must fall to such a value that the arc will go out and terminate the charge. If, however, the battery is in bad condition and cannot be charged up to 2.55 volts per cell the current will never fall low enough to cause the arc to go out and the outfit will continue charging indefinitely until stopped by hand. If this current is only seven or eight amperes it will do little harm and will often do good as a "gassing charge" if not continued too long or occurring too often. If, however, it should be 12 or 15 amperes it would overheat and injure the battery. The same thing would occur even if the batteries were in good condition in case the line voltage was higher at the finish of the charge than that specified.

The tilting mechanism consists of an alternating-current magnet supplied with current from a small tilting transformer connected across the power line. The primary of this transformer is in series with the fixed and movable contacts of a relay mounted on the rear of the slate panel which carries the dial switches. Normally a counterweight lifts the relay plunger closing this circuit. When the line switch is closed the primary of the tilting transformer is energized and the secondary delivers current to the tilt magnet. This causes

the bulb to tilt by means of a spring connection between it and the magnet plunger until the mercury pools come together and short-circuit the magnet. The bulb is then released and tilts back, separating the mercury pools and thus breaking with a spark the short-circuit current of the tilt transformer. If the main arc does not start up the bulb tilts again, but if the main arc does start the direct-current flows through the relay coil and draws down its plunger, thus separating the relay contacts and stopping further tilting by opening the primary circuit of the tilt transformer. If now the direct current through the relay coil is too great it draws down the plunger so hard that its downward pressure trips a circuit breaker latch, which is combined with the relay and opens both the alternating-current and the direct-current circuits. In this case a lower dial setting must be taken and the rectifier restarted after first resetting the breaker by turning the reset handle between the dials.

Inasmuch as the current through the two mercury pools is alternating, and as the arc starts to the one that is negative, there is an even chance of the arc starting on the supplementary instead of on the main pool. If it continued there it would crack the seal and destroy the bulb. As a matter of fact, however, if the arc does strike to the supplementary electrode, it passes out through the tilt magnet which at once tilts the bulb again and brings the pools together, thus transferring the arc to the main pool. If the power should go off the line suddenly or the bulb should stop for any other reason before the current fell lower than 10 amperes the relay plunger would be released and the counterweight would fall, bringing the relay contacts together ready to cause the bulb to tilt and start up again as soon as the power came on. If, however, the charge continues until the current has fallen to 10 amperes or less, the counterweight slips back slowly a short distance and a latch engages the counterweight rod in such a way that it cannot fall back any farther when the arc goes out. This is in order to prevent the outfit from continuing to tilt indefinitely when the outfit stops automatically at the end of charge. Such indefinite tilting, however, would cause no harm as both magnet and tilt transformer are designed to stand continuous tilting without overheating. In fact the tilt transformer is designed with such a high leakage reactance that it will stand having its secondary short-circuited continuously without injury. Indefinite tilting is, however, undesirable mechanically, even if it is harmless electrically. For this reason difficulty is

encountered where it is desired to use a rectifier with a car that is equipped with an ampere-hour meter. These latter are usually supplied with a circuit breaker in the direct-current circuit that is tripped by the meter when a pre-determined number of ampere-hours has passed into the battery. This breaker, accordingly, may trip at a value of current above 10 amperes, and as it does not open the alternating-current circuit the bulb would proceed to tilt till someone opened the line switch. In such a case either a non-automatic rectifier must be used in spite of its inability to restart, or a three-conductor plug used and the circuit breaker arranged to open the alternating-current instead of or in addition to the direct-current circuit.

In actual use of the rectifiers many questions often arise and an attempt has been made below to give a few of these together with answers to them.

Q—How can an outfit be adjusted for different numbers of cells?

A—By setting the dial. There are twenty-five possible settings.

Q—How should the bulb be adjusted for proper tilting?

A—The springs should be so adjusted that the bulb stands in a vertical position normally with the magnet plunger clear up. In tilting the plunger should pull down to the bottom of its possible travel and in so doing should tilt the bulb till the mercury pools come well together. The bulb should swing back far enough to completely separate the mercury pools.

Q—If an outfit fails to tilt what is the probable cause?

A—First try the circuit breaker reset knob. It may be that the circuit breaker has tripped or that the latch is in engagement and is holding the relay contacts apart. If this is not so, examine the relay contacts to see if they are clean and make good contact, and notice whether the flexible lead to the moving disk has broken off. If the relay contacts are together and are making good contact and still the bulb does not even start to tilt there must be an open or short circuit somewhere in the wiring, or the pools in the bulb do not separate, in which case the setting of the bulb should be adjusted.

Q—When the bulb tilts properly but fails to start up, what should be done?

A—First see if the charging plug is in the vehicle and all connections to the bulb, etc., are properly made. Next try a higher dial setting, but not too much higher unless the outfit is equipped with a circuit breaker. Notice whether a good spark is obtained in the bulb when the mercury pools separate. Then notice whether a white glow flashes from the anodes when the spark occurs at the mercury pools. If not there probably is an open circuit somewhere, perhaps a bad contact on the dial switches. By far the most common cause for difficulty in starting is a cold bulb. The only cure in such a case is to take the bulb out and warm it up.

Q—When a rectifier fails to stop at full charge, what are the usual causes?

A—If the outfit fails to cut out at all, but continues to run, the line voltage is probably high or the battery is in bad condition and has not risen to the voltage it should at full charge. The line voltage considered in choosing the proper dial setting should be the open-circuit voltage at that time of day or night when the charge is to be completed; not that at the start of charge or at full load. If the outfit cuts out too soon a higher dial setting should be used, usually one notch higher on the right hand dial.

Q—How can an operator tell when a bulb has become useless?

A—Remove the bulb and shake it. If the mercury gives a metallic click, the vacuum is still good. If the bulb seems very dirty inside and if the mercury clings to the glass and plates it, the vacuum is poor. Usually in such a case the bridge between the two mercury pools becomes plated and thus short circuits the tilting magnet and prevents the bulb from tilting or starting.

The outfits above described are of the automatically re-starting type. For public garages, factories or other places where attendance is available at all times, or where the user is willing to take the chance of the outfit stopping occasionally a non-automatic type of outfit can be used that is somewhat simpler and cheaper in first cost. The non-automatic rectifier is similar to the automatic type in appearance, but has no tilting magnet or circuit breaker. Instead it is tilted by hand and is protected by a fuse in the direct-current circuit. The tilting is done by turning a knob in the center between the dials. This knob, besides tilting the bulb, also makes a contact on a rear auxiliary dial and accordingly should be held over in position long enough to give the bulb a chance to start up before releasing it and allowing it to snap back. As these outfits are non-automatic in starting they are likewise non-automatic in stopping; that is, the reactances are so adjusted that the outfit finishes a charge at a current of 12 to 14 amperes instead of five or six amperes, as in the automatic type. This current is well above the going-out value of the arc, so the charge must be terminated either by opening the line switch by hand or by some sort of time switch.

During the time that lead batteries were used exclusively 30 ampere outfits were large enough for everything except public garage use. Since the introduction of the Edison battery, however, there has been a demand for a rectifier capable of delivering 45 or 50 amperes, which is about the limit for which rectifier bulbs can be made of glass. Accordingly, outfits have been developed having a 50 ampere rated output and a comparatively flat regulation slope. This is because the Edison cell is properly charged at a high

rate throughout the charge, instead of requiring a finishing charge at a low current like the lead cells. For this reason a larger reactance coil is used in series with a transformer of a special design and adjustment such that the outfit starts charging by delivering 50 amperes to fully discharged cells and finishes charging at from 30 to 35 amperes. These outfits, shown in Fig. 5, cover a range of from 20 to 54 Edison cells and have two seven-point dials giving 49 possible points of adjustment. The same automatic tilting system is used as on the automatic 30-ampere outfits. A simple relay, however, is used instead of a combined relay-circuit breaker, and each outfit has a small panel mounted on top carrying a line switch, fuses and a direct-current carbon circuit-breaker. These outfits have the same general characteristics as the 30-ampere rectifiers except that as they are designed primarily for use with Edison cells they are adjusted for a 26 percent rise in voltage from the beginning to the end of a full charge instead of for an 18 percent rise, as in the case of the outfits intended for use with cells.

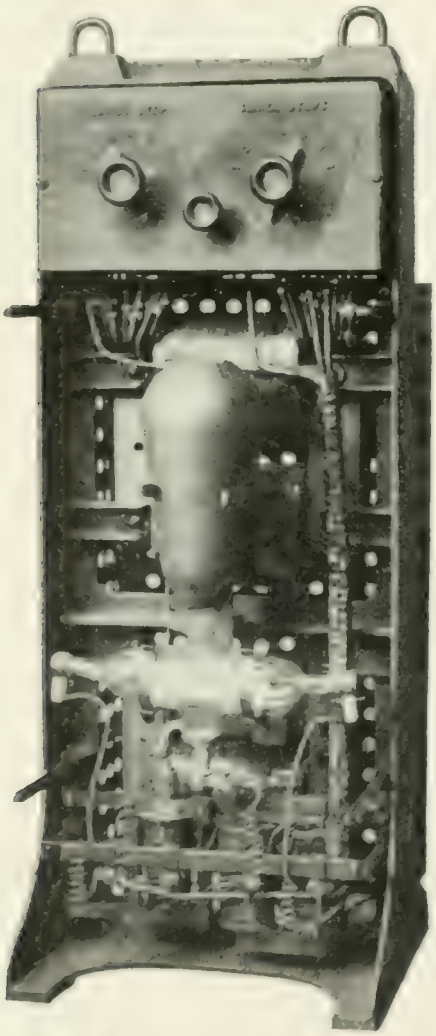


FIG. 5—AUTOMATIC STARTING, 50 AMPERE RECTIFIER FOR EDISON CELLS

ARC LAMP OUTFITS.

While most rectifier outfits are used for charging storage batteries the mercury rectifier is not limited to that field alone. The type shown in Fig. 6, for example, is designed to deliver direct current instead of alternating current to moving picture arc lamps. Two styles are manufactured, one for use on 110 volt and the other on 220-volt alternating-current lines. The great majority of moving picture theatres that are not located near the center of some large city, have only alternating current available and in very few cases do the owners go to the expense and trouble of installing a motor-generator set in order to obtain direct current. The result is

that these theatres use an alternating-current arc light either with resistance in series or in connection with some kind of economy coil. The use of the latter, it is true, saves half or two-thirds of the power that is wasted in the series resistance method, but in either case the alternating current arc is far from satisfactory as a means of illuminating moving pictures. This is because, in a direct current arc, the light is concentrated at one point, namely the crater on the positive carbon, while in an alternating-current arc the light is distributed over the whole arc length. This concentration of light at one point in a direct-current arc gives much greater light intensity for the same watts consumption and is especially suited for projection through a lens. Likewise the quality of the illumination with an alternating-current arc suffers somewhat because of the superposition of the arc frequency upon the frequency of the pictures themselves. This is especially true on low arc frequencies, such as 25 cycles, and where rapid movements are being shown and every picture must be seen to get the full effect. This trouble, of course, does not exist with a direct-current arc and for this reason the use of a mercury rectifier will greatly improve the illumination of the pictures wherever an alternating-current arc has hitherto been used. The mercury arc is much more efficient than an alternating current arc in series with resistance for moving picture work, and is probably more efficient from a cost of power standpoint than an alternating-current arc operating from an economy coil, because in the latter case it is usually necessary to use nearly 50 percent more current in the arc in order to get anything like as good illumination. The efficiency of the rectifier is about 65 percent.

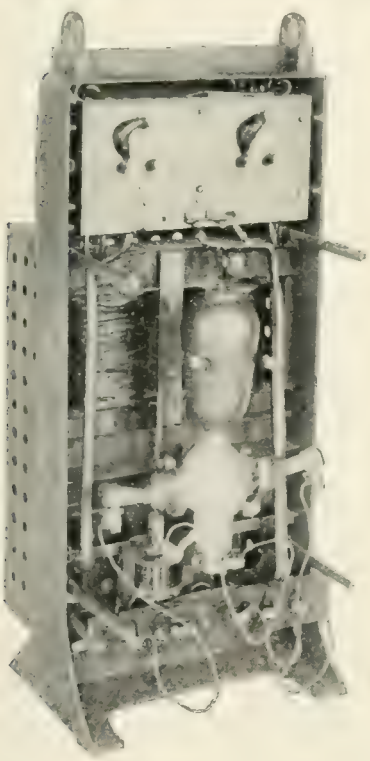


FIG. 6—AUTOMATIC STARTING, 30 AMPERE RECTIFIER FOR USE WITH MOVING PICTURE ARC LAMPS

These outfits are entirely self-contained in one unit and can be moved about as desired. They take very little floor space and the two line wires from the power circuit and the two direct-current leads to the arc form the only exposed wiring. They consist essentially of an iron frame on which are mounted an auto-transformer having a reactance coil connected in series with its primary,

a mercury bulb, a tilting magnet and a relay controlling the latter. There is also a slate panel bearing four binding posts to which are wired taps from the transformer. These are for adjusting the outfit to line voltages slightly higher or lower than normal, and this initial adjustment is the only one that need be made.

In operating this type of mercury rectifier, the connections should first be made to the proper binding posts according to the line voltage. The line voltage to be considered is not the line voltage on open circuit, but the actual line voltage at the outfit when it is operating at normal full load. If the proper connections are made and the line switch closed the outfit is started up by bringing the carbons together. This completes the circuit through the tilting magnet and the bulb should at once begin to rock. One or two tilts should be sufficient to cause the arc to start up, whereupon the carbons should be at once separated till the best light is obtained. Each outfit is adjusted to deliver 30 amperes at 45 to 50 volts if the proper connections have been made according to the line voltage. Four different line voltages are provided for on both the 110 and the 220-volt outfits. Inasmuch as the bringing of the carbons together in starting short circuits the transformer there is a reactance coil connected in series with the primary of the transformer which limits this current to not over about 44 amperes direct current, thus resulting in a low power-factor. If resistance instead of a choke coil had been used the power-factor would have been improved, but the efficiency would have been lowered greatly. This low power-factor involves larger primary current, but does not mean the large power bill that the large current might seem to indicate.

Bulbs are commonly guaranteed for 50 hours' use, but there should always be an extra bulb on hand to guard against accidental breakages. If an operator happens to break his last bulb his outfit is not necessarily entirely out of commission, as he can use the outfit as an economy coil for an alternating-current arc until he can get another bulb by making a very slight change in the connections for which the manufacturers can give him directions.

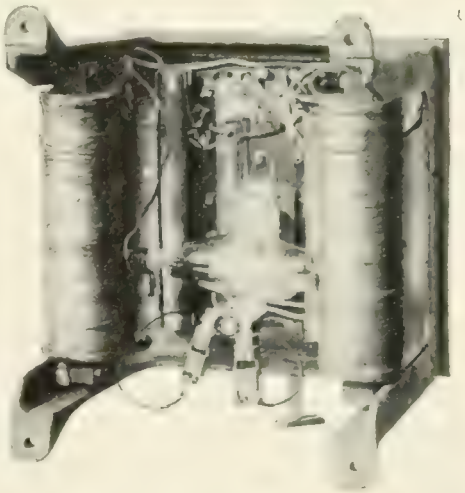
IGNITION BATTERY CHARGING OUTFITS

Another use to which mercury rectifiers can be applied is the charging of the small ignition and lighting batteries used on gasoline automobiles. For this service two different outfits are manufactured, known as the five and ten ampere rectifiers. The former is designed to charge from one to seven cells at a current, varying

from five to about four amperes during charge. It is so wound that the same outfit can be operated from either 110 or 220 volts by simply changing two link connections. No other adjustments are provided and in operation the battery is simply connected from the stud marked + to the stud bearing a figure corresponding to the number of cells to be charged. The outfit is started by tilting the bulb by hand by means of a knob on the face of the panel.

The ten ampere outfit is designed to charge from three to ten cells at a maximum current of ten amperes. This outfit also is hand starting and is designed to operate on either 110 or 220 volts. It is, however, equipped with three adjustment dials, the upper two varying transformer taps and the lower one varying a series resistance.

Both of these outfits are so simple that they are practically devoid of operating trouble and in addition the bulbs have exceptionally long life at these low currents and voltages. The only difficulties that might be encountered are as follows:—



Rear view showing bulb.

FIG. 7—5 AMPERE RECTIFIER FOR CHARGING AUTOMOBILE IGNITION BATTERIES

A—Difficulty in starting—This may be due to cold bulb, too low dial setting, or to an open circuit, especially in the series or shunt resistance. In case a resistance has burned out it can be temporarily replaced by a bank of lamps.

B—Bulb may go out during charge—This may be due to a momentary interruption in the power service, in which case tilt the bulb and start it up again; or it may be due to the dial setting being too low so that the current fell so low that the arc could no longer sustain itself. In this case tilt and restart at a higher dial setting.

Standard rectifier outfits for any of the purposes mentioned are adjusted for 60 cycle operation. Similar outfits can, however, be designed for any other desired frequency. The only changes involved are in connection with the transformer and reactance coil, for the operation of the rectifier bulb is independent of the frequency. In fact the writer has operated a standard bulb on as high as 200 000 cycles per second with no more difficulty than on 60 cycles and with no difference in appearance to the eye.

POWER-FACTOR CORRECTION BY ROTARY CONVERTERS IS HAZARDOUS

NICHOLAS STAHL

A graphical method of calculating power-factor conditions in loaded power circuits was published in the October, 1911, issue of the JOURNAL. The fact was mentioned that the power-factor of a circuit may be less than unity, due either to a load having a capacity component of current and thereby giving a leading power-factor, or to a load having an inductive component which causes a lagging power-factor. It was also explained that by supplying to the system additional current of opposite reactive characteristics to that causing reduction of power-factor, the latter can be raised by an amount depending upon the relative magnitudes of the various components of the load. Thus a load, with low power-factor, due to inductive apparatus, can be given a power-factor approaching unity either by adding sufficient non-inductive load, or, more particularly, by adding a load with capacity characteristics, thus introducing current with a compensating leading component. The article also discussed the use of alternators, such as synchronous motors for supplying corrective current, either leading or lagging.

A warning was sounded regarding the inadvisability of utilizing rotary converters for power-factor correction without due consideration, notwithstanding the fact that, considered from the alternating-current standpoint, they possess the characteristics of a synchronous motor. But the purpose of this article is to show in more detail the danger involved in attempting such over-excitation and to indicate the limitations of this method.

Before entering into details, it is well to note that, as suggested above, the operation of the rotary converter merely at 100 percent power-factor introduces of itself a very considerable corrective effect simply by the addition of so many k. v. a. at the highest power-factor into the system to be improved.

IN its ordinary application, the rotary converter is a machine supplying direct-current power and receiving power from an alternating-current source. At certain instants during the rotation of the armature of a converter, the current flows into the armature winding through a collector ring, to the commutator, and out through the direct-current brush without need of commutation. In the coils adjacent to the collector ring the alternating-current then flows in the same direction as the direct current, while in the coils toward the middle of the phase the alternating and direct currents are opposed. While this condition changes from instant to instant, the net result for a complete cycle is a considerably greater current in the coils next to the alternating-current terminals, or tap coils. Hence, assuming normal full-load operation and neglecting losses in the machine, the heating of the different coils is not the same for all points between collector ring taps, but is, generally speaking, greatest at the ends and least in the central regions. The increase in heating towards the ends is, however, not uniform but takes place at a much more rapid rate

than that proportional to the distance measured along the periphery of the armature.

Under conditions of unity power-factor, the heating of each half of the phase is symmetrical. But when the power-factor is lagging, i. e., when the rotary converter is under-excited, the distribution of heating is changed; that coil of a phase which is ahead with respect to rotation is heated very much more than any other coil. As the power-factor decreases this increase in heating becomes greater; simultaneously, the originally equal heating of the rear coil of the phase grows less, while the coil of least heating moves backward with respect to physical rotation from the center coil toward the rear, so that when a certain lagging power-factor is reached the coil of the least heating is actually the rear tap coil. In practice, however, before reaching such a condition of operation the front tap coils would be very much overheated.

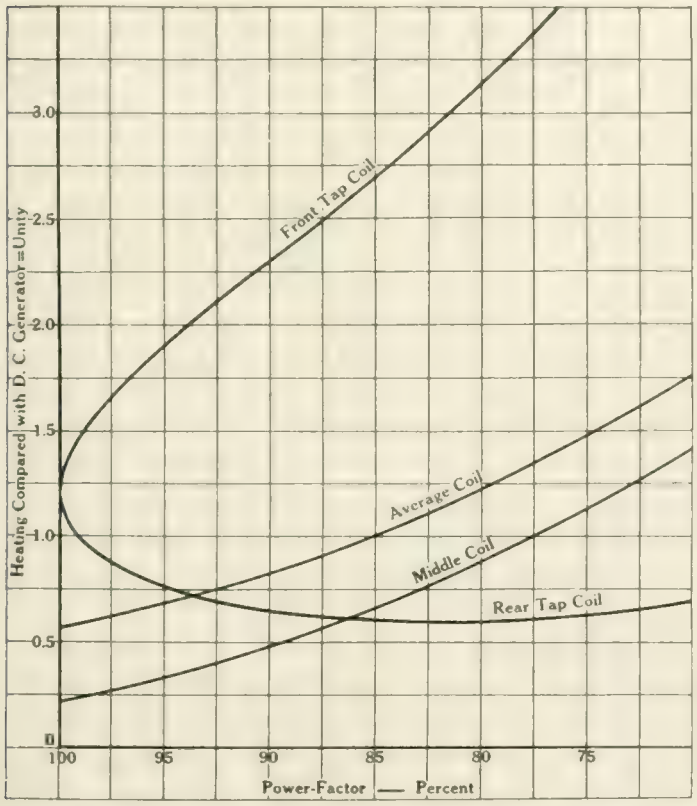


FIG. 1—DISTRIBUTION OF HEATING IN COILS OF THREE-PHASE ROTARY CONVERTER, CORRESPONDING TO VARIOUS VALUES OF LAGGING POWER-FACTOR

For leading power-factors, reverse values for front and rear tap coils.

These conditions are shown in detail in Figs. 1, 2 and 3* for coils of three-phase, two-phase, (four ring), and six-phase rotary converters, whether diametrically or double-delta connected, with power-factors varying from unity to approximately 70 percent lagging or leading. In each curve there is plotted the heating for the front and rear tap coils, the average coil, and the middle coil of the phase; the comparisons being based on the assumption of unity heating when the machine is run as a direct-current generator. The

*These curves are reproduced by permission from an article by the author in the *Electrical World* for October 28, 1911, p. 1060, which gives their mathematical derivation.

permissible ratings of these machines on the basis of the heating of the average coil are shown in Fig. 4. The lowest curve* in Fig. 4 represents the permissible rating of a six-phase rotary converter with transformers diametrically connected when one of the original three transformers has been disconnected; the case is the same as a two-phase converter with unsymmetrically arranged transformers, 60 degrees (or 120 degrees) out of phase with each other, instead of 90 degrees as ordinarily. This introduces such very considerable circulating currents as to decrease the rating of the converter even below that of the three-phase machine.

In connection with this latter figure, it is interesting to follow the rapid drop in rating for a very slight change in power-factor from unity, *even for average coil conditions*. For example, at 95 percent power-factor the six ring, four-ring, three-ring, and unbalanced phase machines show respectively only 86 percent, 87.5 percent, 91 percent and 85 percent, respectively, of their permissible rating at unity power-factor.

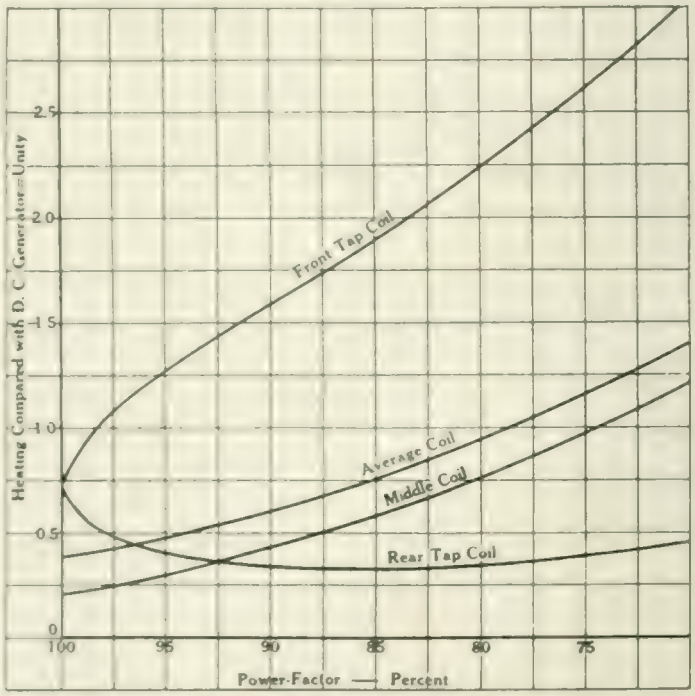


FIG. 2—HEATING OF COILS OF TWO-PHASE (FOUR-RING) ROTARY CONVERTER; LAGGING POWER-FACTORS

For leading power-factors, reverse values for front and rear tap coils.

This restriction is increased if, as is necessary from the operating standpoint, the ratings are to depend solely on the worst or front tap coil heatings with lagging power-factor, or with leading

*In the case of the three-phase or of the six-phase machines when the transformers of the latter are connected in double delta and for some reason one of the transformers is disconnected, it is sufficient to remark that the load which may be carried is limited by the outputs of the two transformers left in open delta, or "V." Should these be operated to give normal full-load current on the low-tension side, such transformer will be carrying an overload of 15.5 percent, and the rotary converter will, of course, be operating at only two-thirds of its rated output, with corresponding heating. There are no unbalanced currents in the converter armature. However, the case is different with a six-phase converter for which the transformers are diametrically connected.

power-factor, on rear coil heatings; the corresponding figures at 95 percent power-factor are, for six-ring, four-ring, and three-ring machines, 72, 76, and 79.4 percent respectively.

The more rapid fall of rating of machines of a higher number of phases points to the importance of unity power-factor operation. This, of course, is not to be construed as an argument in favor of a machine with fewer rings. Fig. 4 brings out clearly the difference in the allowable rating of the same machine operated with various numbers of rings, but this latter discussion is merely intended to show that the *decrease in relative rating* is more rapid with the greater number of rings; so that, while at 100 percent power-factor the same machine operated three-phase would have only 69 percent of its rating when used as a six-phase machine, at 70 percent power-factor, for example, operating three-phase, it would have about 84 percent of its six-phase rating; yet a given three-phase converter at 70 percent power-factor would have only 55 percent of its three-phase rating at 100 percent power-factor. The six-phase machine at 70 percent power-factor has only 47 percent of its rating at 100 percent power-factor, these latter ratings all being based on average coil heatings. The curves, whether for average coil or tap coil conditions, indicate also a rapid approach of all the machines to the same very low ratings as the power-factor becomes very low.

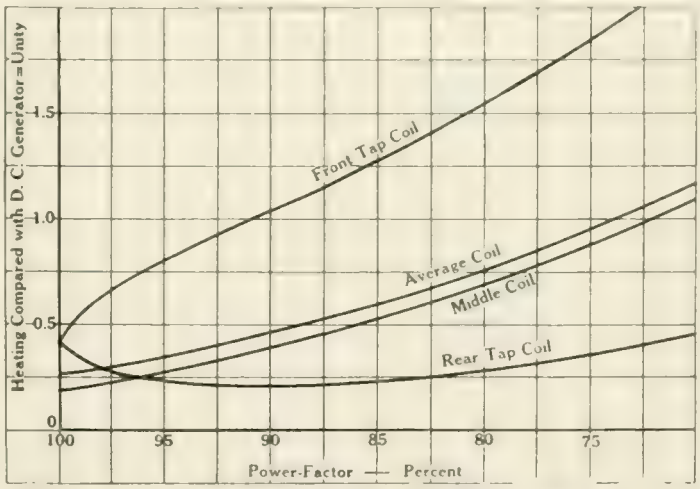


FIG. 3—HEATING OF COILS OF SIX-PHASE ROTARY CONVERTERS; LAGGING POWER-FACTORS

For leading power-factors reverse values for front and rear tap coils.

It is interesting to note in Figs. 1, 2 and 3 the values of power-factor at which the rear tap coils have the same heating as the middle and average coils. For the middle coil in six-ring, four-ring, and three-ring machines this occurs at power-factors of 96.5, 92.4, and 86.5 percent, respectively, while for the average coil the figures are 98.2, 96.5, and 93.7 percent.

The inequality in the heating of the various coils suggested at one time the manufacture of rotary converters with coils of various cross-sections, increasing from the middle towards the ends of the

phase, but it is obvious that modern commercial manufacturing conditions preclude any such procedure; all of the coils are made of the same cross-section, and hence, it is the heating of the worst coil which determines the safe rating of the machine, or if this is exceeded, the point of probable burnout. The curves have been drawn on the further assumption, borne out by test, that very little, if any, of the heat developed in an individual coil is conducted to neighboring coils, but is dissipated principally at the point of generation, which involves corresponding local temperature differences.

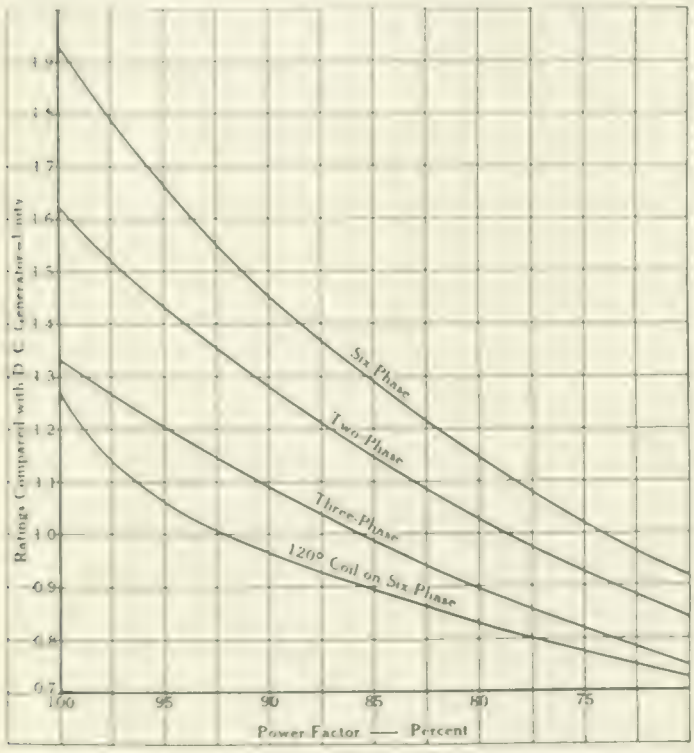


FIG. 4—RATINGS OF THREE-RING, FOUR-RING AND SIX-RING ROTARY CONVERTERS FOR EQUAL AVERAGE HEATING

The bottom curve represents the special condition of a diametrically-connected converter with one transformer omitted, giving, in effect, a distorted two-phase connection (one-phase = 60 degrees; the other = 120 degrees). Maximum heating occurs in 120 degree coil.

This inequality in heating lends emphasis to the insistence in the present article that converters should be operated at very nearly 100 percent power-factor when fully loaded. This contention is strengthened in the case of compounded converters using reactance of 15 to 25 percent in the alternating-current circuit with a line drop of about five to ten percent in order to secure flat compounding, for even then it is common practice to adjust the field so as to secure 100 percent power-factor at not more than full load, and possibly more often even at 75 percent load, and in a number of cases at 50 percent of full load. As stated above, with these reactances and the shunt field adjustments indicated, the machines will have power-factors ranging from approximately 98 to 93 percent leading, from full load to 150 percent load.

If the heating due to this cause is added to that produced by the overload (which varies as the square of the load current), the

total heating may be found as follows:—Referring to Fig. 3, the equivalent heating value in front and rear tap coils corresponding to 100 percent power-factor is determined as 0.418. Likewise the equivalent heating in the rear tap coil at 95 percent power-factor leading (rear tap, since the wattless current is now leading) is found to be 0.8. Then, for the six-phase machine at 150 percent load and 95 percent power-factor leading, the total heating in the rear tap coil will equal $\frac{0.8}{0.418} \times (1.5)^2 = 4.32$ times that at full load and unity power-factor.* For the three-phase machine, the figure would be 3.06, the four-ring machine having an intermediate value. It is clear that the machine is in no danger at low loads even at very poor power-factors, but in this case the k. v. a. being applied to the machine is correspondingly small and the corrective effect on the power-factor of the system of little moment.

Since it is common practice at present to operate rotary converters for periods of two hours or more at 150 percent load, Fig. 5 has been plotted to show the loads which may be carried at various lagging power-factors, with the same heating in the *front tap coils* as exists at 150 percent load and unity power-factor. Had the curves been made on the basis of average heating the slopes would not have been so abrupt, but would have indicated the same tendency.

The curves may serve as an additional check on the safe loading of such machines as are arranged for unity power-factor operation through field adjustment at high loads, and correspondingly lower power-factors at lower loads. Moreover, as the corresponding curves based on heating equivalent to other loads than 150 percent at unity power-factor are of practically the same form as those of Fig. 4, a clue to the limiting heating at various power-factors with other assumed conditions of loading may be obtained from these

*The relations are expressed by the equation,

$$Ax^2 = By^2.$$

in which,

A=Heating at given load and 100 percent power-factor, expressed in terms of heating of machine operated as a direct-current generator.

B=Heating, relative to direct-current machine, at the same given load and new power-factor.

x=percent current at the given load and 100 percent power-factor.

y=percent current at new load and new power-factor.

In the present case, $A=0.418$, $B=0.8$, $x=1.5$. Then to determine y^2, as a measure of the heating corresponding to y,

$$y^2 = \frac{0.8}{0.148} \times (1.5)^2 = 4.32.$$

curves by substituting suitable new values for the "load" coordinates.

The caption of this article is not to be construed as indicating that rotary converters may have no corrective effect on power-factor; it is intended rather, as a brief presentation of the dangerous heating which results in certain coils when the machine is operated at normal load or overload, at power-factor other than unity; in most commercial systems it is only when rotary converters are operated under these latter conditions that the leading wattless k.v.a. input to them would be of sufficient magnitude to bring about any appreciable betterment of power-factor. Of course, with under-loads of reasonably steady characteristics, such as lighting service, the corrective effect securable by leading power-factors on the converter may be employed with safety up to the points indicated by Fig. 5. With fluctuating railway loads, where compounding by reactance and series field action is common, the converter will be under-excited and therefore will have a lagging power-factor at low loads; here also, Fig. 5 may be used as a guide, not, of course, for corrective purposes, but as an indication of permissible heating, though these curves must not be construed as giving any information regarding the compounding to be secured with a given load.*

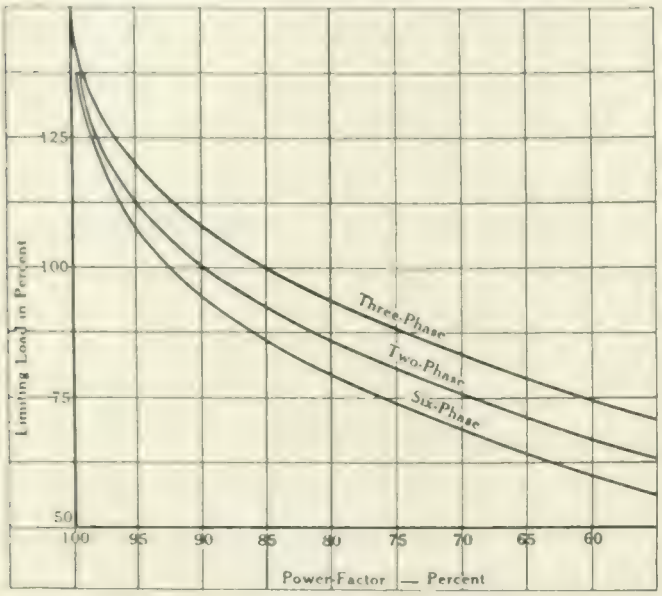


FIG. 5—LIMITING LOADS CORRESPONDING TO VARIOUS LAGGING POWER-FACTORS, ON THREE-RING, FOUR-RING AND SIX-RING ROTARY CONVERTERS FOR HEATING EQUIVALENT TO 150 PERCENT LOAD, AT 100 PERCENT POWER-FACTOR

Approximate corresponding values based on heating equivalent to other loads at 100 percent power-factor can be obtained by substituting the new value for *150* and revising the ordinates accordingly.

*This phase of the subject was treated in detail in an article by Mr. Jens Bache-Wiig in the JOURNAL for November, 1910, p. 860.

SOME OBSERVATIONS ON THE METALLIC ARC

G. M. LITTLE

IN 1905, shortly after the mercury arc rectifier had been developed, an investigation of some of the more efficient arc lamps and electrodes then on the market was started. Among these was a direct-current lamp which burned electrodes made of oxides of iron, titanium and chromium, the current being supplied by an arc light generator, or by a mercury arc rectifier from an alternating-current source. This lamp gave good results but was evidently open to improvement. Its chief peculiarity was the fact that the arc apparently was burned wrong end up, the bright end of the arc being below.

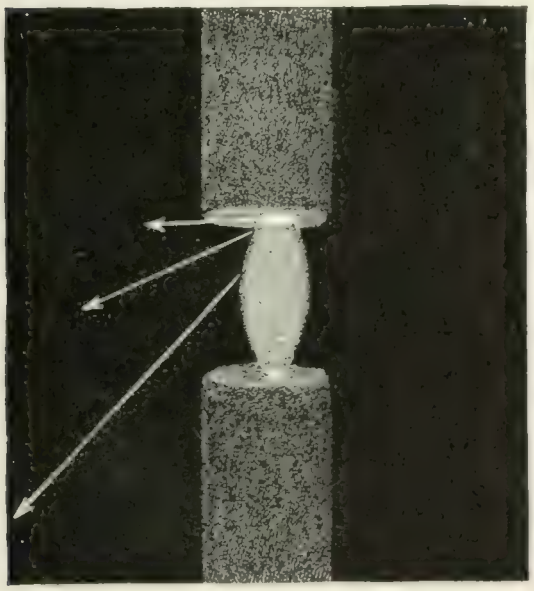


FIG. 1

Appearance of direct-current carbon arc burned with bright crater above. The arrows indicate roughly the direction and intensity of the light. The arc itself is relatively non-luminous. Normal position.

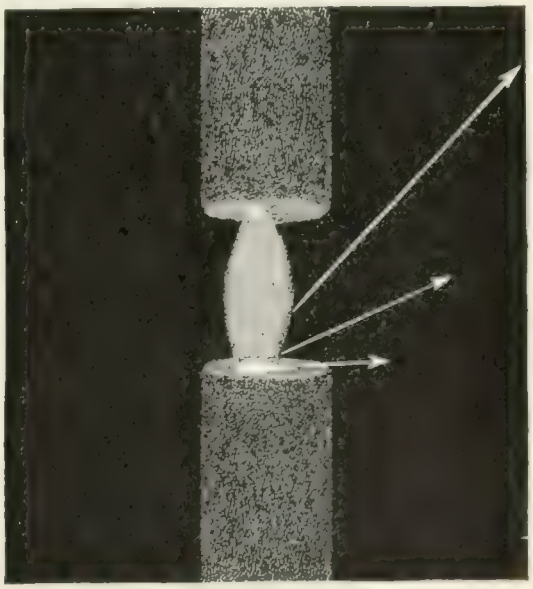


FIG. 2

Appearance of direct-current carbon arc burned with bright crater below. The arrows show how the light is wasted by being thrown above the horizontal.

Direct-current *carbon* arc lamps have always been burned with the bright crater above. The reason for this is obvious, as the light given out by these carbons is generated almost entirely by this bright crater on the end of the upper electrode, which causes most of the light to be thrown below a horizontal plane drawn through the crater, as indicated in Fig. 1. This uneven distribution of the light becomes very noticeable when by chance a carbon lamp is allowed to burn with its polarity reversed, or as it is termed "up side down," for in this case the bulk of the light is thrown upward, as shown in Fig. 2. It is evident that this latter method would be very wasteful of the light as that which is thrown above the hori-

zontal is practically of no value, with perhaps the exception of such portion as might be reclaimed through the use of reflectors to direct it downward.

With these well established facts in view, an examination of the action of the light generated with electrodes made of metallic oxides (oxide of iron, titanium and chromium) showed a very interesting parallel. In this case the light comes almost entirely from the brilliantly luminous arc itself. The arc, however, is never equally luminous over its entire length and there is always a power-

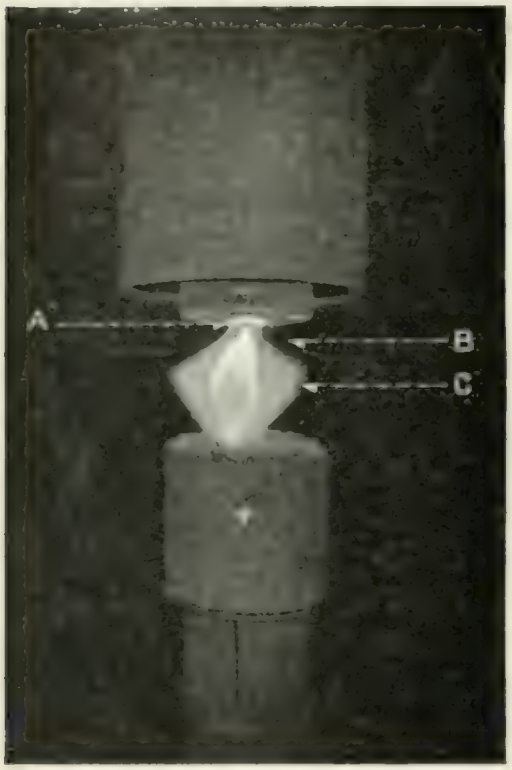


FIG. 3—THE METALLIC ARC, "BRIGHT END UP"

A—Pool of slag, on the end of the upper, negative electrode, in which is seen the reflection of the brightest portion of the arc. *B*—Non-luminous envelope of soot surrounding only the upper part of the arc. *C*—Yellow, faintly luminous vapor.

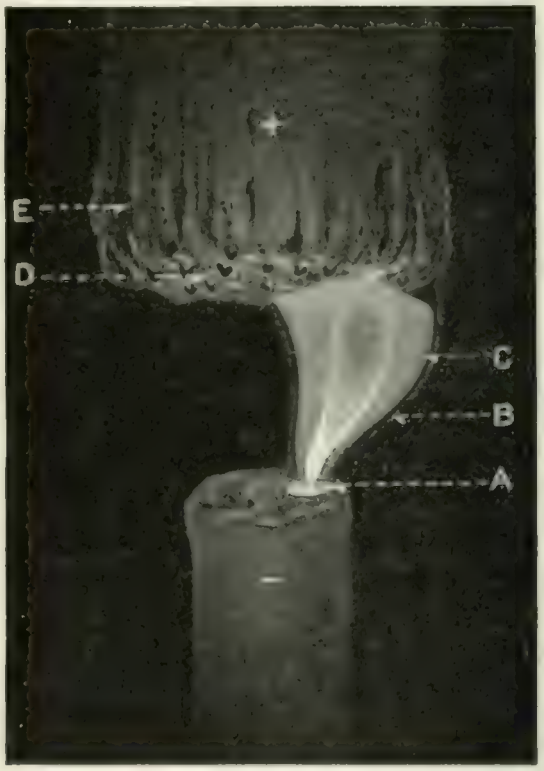


FIG. 4—THE METALLIC ARC, "BRIGHT END DOWN"

A—Pool of slag, on the end of the lower, negative electrode, in which is seen the reflection of the brightest portion of the arc. *B*—Non-luminous envelope of soot completely surrounding the arc. *C*—Yellow, faintly luminous vapor. *D*—Globules of fused soot. *E*—Soot deposited on upper positive electrode.

ful reflection from the pool of molten slag which exists on the end of the negative electrode.

These facts hold true, moreover, no matter which electrode is above and which below, as shown in Figs. 3 and 4. The arc is generally very bright for about one-eighth of its length at the end adjacent to the negative electrode, and gradually diminishes in brilliancy as the positive electrode is approached, becoming relatively small when within one-fourth of its length of that electrode.

Considering the powerful reflecting effect of the pool of molten

slag, with which the brightest end of the arc is in immediate contact, it may be seen that if the electrodes are burned in such a way that the bright end of the arc and the reflecting pool of slag are above, a distribution of the light will be obtained in which the larger amount is below the horizontal, while if they are arranged in the reverse way the bulk of the light will be thrown above the horizontal, which will necessitate reflectors to obtain this portion as useful light. This was very positively and satisfactorily shown by photometric measurements of the mean lower hemispherical



FIG. 5—METALLIC ARC, BURNED BRIGHT END DOWN, AS IT APPEARS DURING A "DIM SPELL"

The luminous portion of the arc is seen to be almost entirely absent. There is no envelope of soot.

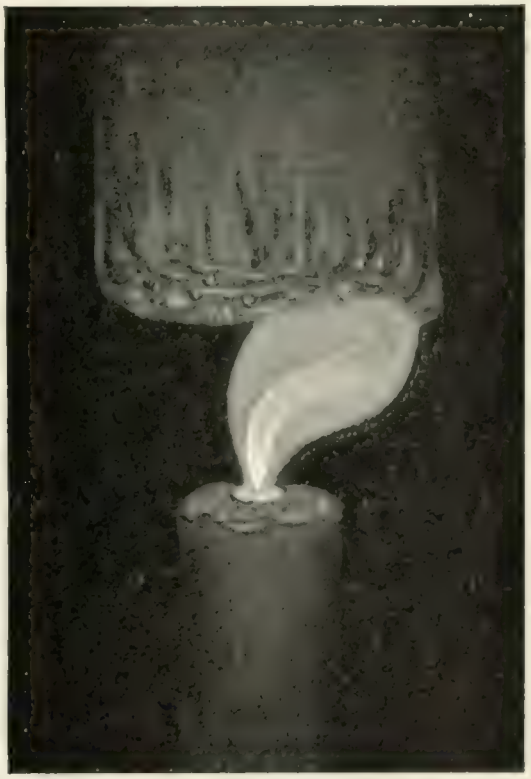


FIG. 6—METALLIC ARC, BURNED BRIGHT END DOWN, SHOWING FREQUENT DISTORTION OF THE ARC

Probably caused by the obstruction of the air draft by the large flat under surface of the upper electrode.

candle-power, the candle-power per watt being decidedly lower with the bright end down.

In addition to this the arc, when burned with the bright end below, develops some peculiarities which are absent when it is burned with the bright end above. For instance, almost none of the light from the brightest portion of the arc, *i. e.*, next to the negative electrode, reaches the ground in the immediate neighborhood of the lamp, as it is screened by the lower negative electrode owing to the flat shape which it takes. This effect is proportional to the diameter of the negative electrode. Moreover, the arc is surrounded

by an envelope of soot which not only contributes nothing to the light, as it is not in the interior of the hot arc stream where it would be heated to incandescence, but acts to cut off some of the light generated in the arc itself. This soot envelope arises from the edge of the melted pool of slag (apparently by heat evaporation) and is not projected into the arc by the electric current as are the vapors of the useful light giving oxides which constitute the more central part of the arc.

The electrodes when freshly trimmed, and burned bright end down, give an arc which, during the first 20 hours of burning, is often luminous over its entire length for intermittent and irregular lengths of time, but during the remainder of their life, about 130 hours, the arc seldom if ever becomes luminous over its whole length, and frequent periods of dimness and change of color occur. These dim spells are repeated at intervals of from one-half minute to five minutes, and last from two seconds to three minutes. There is a regular cycle which is followed: First, the light is white; considerable soot is given off, and the arc is luminous over about one-half its length; then the light changes to a blue color; the white, luminous portion of the arc diminishes to less than one-tenth of the total length, as shown in Fig. 5, and the candle power falls to approximately 45 percent of its normal value; this lasts from a few seconds to three minutes when suddenly the light turns white and the arc again becomes luminous over half the length. Sometimes, instead of turning blue, the light turns yellow.

Another cause of uneven performance when the electrodes are burned with the bright end of the arc down is the necessity of using a very large, flat bottomed, upper positive electrode. This obstructs the draft so that, very often, the air currents are moving in a horizontal direction across the face of this electrode, carrying with them the upper end of the arc, which takes the shape shown in Fig. 6. As this occurs, the arc is drawn out to a much greater length, and in consequence, the voltage fluctuates violently, so that, in order to prevent the lamp from "pumping," it is necessary to set the voltage cut-out adjustment of the lamp at about 125 volts, although the arc takes only about 80 or 85 volts when standing vertical. After burning some time the upper electrode shows marked evidence of uneven burning, and as the lamp continues to burn this action of the air, as shown in Fig. 7, becomes more and more pronounced, finally causing the lamp to pump. This is so annoying that these positive electrodes frequently have to be taken

out of the lamp within six months and either reversed or turned up in a lathe. While this item of maintenance cost might seem insignificant when the operation of a single lamp is considered, it becomes a serious one in the case of large installations. The use of a large diameter upper electrode is necessary as this crooked shape forms very quickly if one of small diameter is used.

It is found that the large positive electrode, required for lamps burned bright end down, necessitates the use of a long arc, because the soot that collects on this electrode generally accumulates around the edges to a thickness of one-eighth to one-half inch or more, the effect being to hide the upper part of the arc. This soot collects in very large quantities and has to be removed mechanically. One method of providing for this is to mount the positive electrode so that it is held loosely; accordingly, every time the arc is struck, it is shaken, so that the soot falls to the bottom of the globe where a bowl-shaped receptacle is provided. This receptacle, which holds about a pint, becomes filled with soot between trimmings.



FIG. 7—METALLIC FLAME ARC, BURNED BRIGHT END DOWN, SHOWING INCREASED DISTRIBUTING ACTION OF DRAFT OF AIR WHEN UPPER ELECTRODE BECOMES BURNED OFF CROOKED

Another probable cause for the wide voltage variation found in the operation of this type of lamp is that the relatively long arc required, when burned bright end down, presents a large heat radiating surface. Moreover, the large, cold, positive terminal which is used also exerts a chilling effect on the arc, as a result of which the arc is maintained at only a relatively low temperature—a condition which does not promote stability.

It is found that the presence of copper in a negative electrode is very undesirable, as it causes unsteady light and dim spells during burning. When the arc is burned bright end down the copper oxide which forms on the upper copper electrode falls off from time to time on to the melted end of the lower negative electrode where

it fuses into the slag. Globules of slag (fused soot), which form on the under surface of the upper electrode, also seem to be partly responsible for the dim spells, as the arc will play on one globule a short time, then move over and play on another, and so on, the changes in candle-power often occurring at the time the arc changes its position. These small globules of slag probably have a very large variation in contact resistance, one globule with a large area in contact with the copper having a low resistance, and another globule with a small area in contact with the copper having a high resistance; hence, this may also explain in some measure the change in candle-power as the arc moves from globule to globule.

The features discussed above which were found to be characteristic of lamps of the type in which the arc is burned with the brighter end below, *i. e.*, with the positive electrode above, invited further tests in an effort to overcome these defects. It was found to be difficult to design a lamp which would allow the electrodes to be so placed that the arc would burn with the brighter end up. The arc would "flame" or run up the negative electrode, which would cause wide flucuations in the arc voltage and candle-power. Soot collected on the sides of the upper electrode in the same way as was found in the other type of lamp, hanging down and hiding the light. Accordingly a lamp was built in which the upper electrode was caused to rotate slowly; this, when trimmed with an electrode of small diameter, prevented the "flaming", but the soot still gave trouble.

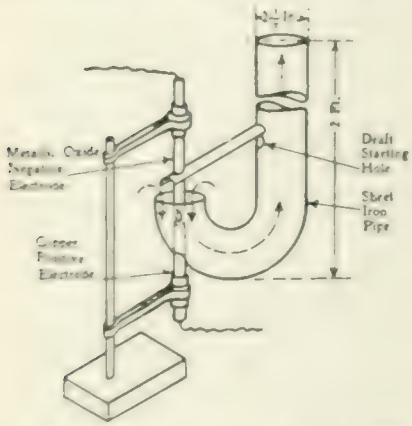


FIG. 8—EXPERIMENT TO DEMONSTRATE THE ACTION OF A DOWN DRAFT ON THE ARC

A lamp was then built in which the arc was surrounded with a rapidly revolving current of air. This held the arc in place but did not take care of the soot. Lamps were fitted with deflecting soapstone plates through which the upper electrode projected, a construction which is commonly used in flame carbon lamps. This was of no benefit as the soot gathered badly.

Finally, after many other experiments, the idea of surrounding the arc with a downward current of air was tried. The experiment was made with a piece of bent sheet iron stove pipe. This was fitted with electrodes as shown in Fig. 8, and a small hole was

provided for starting the draft. When the arc was started it heated the air, which immediately rose and was guided into the starting hole in the chimney, and the down draft was thus formed around the arc. This crude affair showed that the arc could be burned satisfactorily bright end up. No soot collected on the upper electrode and the arc did not run up the side. The records of the Patent Office were then searched, and no record was found of any arc lamp which had this down-draft feature, nor was any found in which the negative electrode was burned above. The development was then made along this line and resulted in the present design of metallic flame arc lamp, details of which are indicated in Fig. 9.

The burning of the arc bright end up permits this lamp to be of a very simple design, in which but one feed clutch is used. This clutch acts directly on the electrode, the arrangement being similar to that commonly used in carbon lamps, where the practice of employing brass rods for the clutch to act upon was abandoned owing to the wear and the fact that they soon became dirty and would stick. In the later type of metallic flame arc lamp no under feed mechanism is needed.

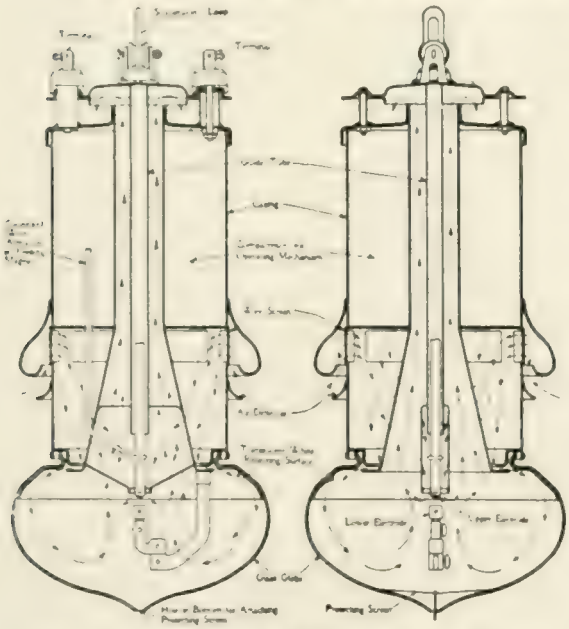


FIG. 9—TWO CROSS-SECTIONS OF SERIES DIRECT-CURRENT METALLIC FLAME ARC LAMP, SHOWING IMPROVED METHOD OF VENTILATION AND SOOT DISPOSAL

The down draft of air is produced by shutting off all openings in the glass globe chamber except certain ones specially arranged at the top. The air is drawn out of the globe by a chimney and the fresh air introduced has to enter by these openings. It is thus directed downward around the arc. The paths of the air currents are indicated in Fig. 9. The construction of the external shell of the lamp and chimney top is such that this natural chimeny draft is much increased during high wind, leading to increased arc stability. The action of the air currents is such that practically all of the soot is carried out through the chimney, instead of being left to collect at the bottom of the globe.

The lamp is so designed that, at time of trimming, both electrodes are renewed, so that the lamp is always free from any effects of a previous run. The positive electrode is a small iron cup in which are coiled ribbons of copper and iron. It is mounted on a small cylindrical stem which is inserted in the lower terminal as shown in Fig. 9. This arrangement serves very materially to reduce the cooling of the electrode, which is of material advantage in its effect upon the performance of the arc. This positive electrode is shown in detail in Fig. 10. It is held tightly in place in the terminal by means of a tightening screw shown in Fig 9, and renewal is made simply and quickly.

Both electrodes are of a type especially developed, through a very considerable amount of research work, for use in this design of lamp. The negative electrode is one half inch in diameter and sixteen inches long. The details of its construction are indicated in Fig. 11. In its composition are included chiefly oxides of iron, titanium and chromium, as in the case of other types of metallic flame lamps. This negative electrode is made in a manner similar to ordinary carbon electrodes, the material being formed into a pasty mass which is forced through a die, dried and baked. A steel wire placed lengthwise through the middle of the electrode serves to carry the current. With this arrangement no sheet iron containing tube for the oxides is required.

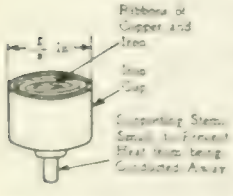


FIG. 10—POSITIVE ELECTRODE

The metallic arc burned with its bright end up and surrounded with a downward stream of air, as in this lamp, develops many interesting features. In the first place the candle-power per watt obtained (figured from the mean lower hemi-spherical candle-power) is found to be much greater than that obtained with the other arrangement of the arc and no "cleaning" draft of air, so that a shorter arc, corresponding to approximately 68 volts, gives at least as much light as an 80 volt arc burned bright end down, and often more. This of course allows more lamps to be put on a circuit for a given amount of power. The strong blast of air quickly removes some of the envelope of soot that surrounds the arc, so that there is less loss by absorption of the light generated in the arc.

The light is not subject to dim spells and changes in color. This improvement is very pronounced and is probably due to several

causes. For instance, no copper gets into the slag on the negative electrode, and there are no small globules of slag having variable contact resistance on the positive electrode. Instead there is one large mass of slag covering a large portion of its top surface, which gives a large low resistance area in contact with the metal. The strong downward flow of air holds the arc in position and prevents it from climbing up the side of the upper electrode, and thus eliminates the large voltage fluctuations. Accordingly the cut-out adjustment of the lamp is normally set at only 95 volts. Although the upper electrodes frequently burn off crooked, with the down draft of air this does not cause nearly as wide voltage fluctuation of the arc as when the bright end is down.

The downward blast of air also prevents the soot from depositing on the upper electrode so that a short arc can be used, the soot not being there to hide any portion of the arc. The short arc presents smaller heat radiating surface and the positive electrode

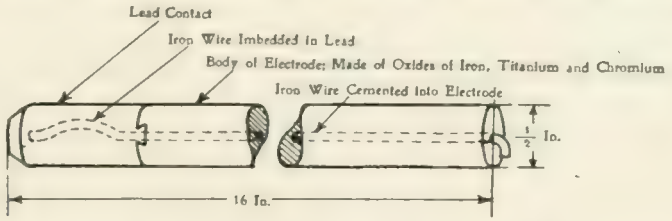


FIG. 11—NEGATIVE ELECTRODE FOR USE IN METALLIC FLAME ARC LAMP

is further kept very hot by mounting it on a small stem which carries off very little heat, as described above. This results in having a very hot arc which probably lessens the voltage fluctuation and gives a higher degree of incandescence to the bright portion of the arc.

It is well known that most of the material fed into the metallic arc comes from the negative electrode, part being electrically projected as a blast and part being simply vaporized by the heat, and it has been noted that very little material is fed in from the positive. While these facts are true, they do not warrant an assumption that an arc which is burned bright end up, the lower end of which is not surrounded by the envelope of soot, is more unstable than when burned the other way. It is true, however, that the stream of material which appears to be electrically projected from the negative electrode is much greater than is necessary to carry the current. In fact, a slow burning electrode (for example, one high in chromium) which feeds material to the arc at perhaps one-tenth the rate of a normal electrode gives an arc that is fully as stable, but which is hardly at all luminous—light-giving materials apparently

not being necessary to the maintenance of a metallic arc.

The evaporation of material from the positive electrode, while small in quantity, and with but small light giving properties, is no doubt amply sufficient to carry the current at its end of the arc, and in the lamp designed for burning the arc bright end up, this evaporation is increased by the above mentioned provision for running the positive electrode very hot. Careful tests of this feature of stability fully prove that, whatever the explanation is, this way of burning the arc gives as stable or more stable results than when burned bright end down. It would appear that the metallic arc is similar to the carbon flame arc in that it is maintained and rendered stable by the non-light-giving materials which, together with light-giving materials, are either electrically projected into the arc or are evaporated from the hot terminals simply by heat. In the flame carbon arc the presence or absence of the vapors of calcium salts (the light-giving materials) does not materially affect the stability of the arc, which is maintained by means of the non-luminous carbon vapor. In the case of the metallic flame arc an electrode having a high percentage of chromium oxide and no titanium oxide gives a very quiet stable arc, yet one which is quite non-luminous. The same is true of a normal electrode passing through a dim spell, the arc being non-luminous yet stable.

An electrode containing a very high percentage of titanium oxide (the main light giving substance in the case of metallic arcs) gives an arc that is brilliantly luminous but very unstable. From this it would appear that, in the case of the metallic arc, the light-giving materials actually decrease the stability due to the non-light-giving materials.

In this article sketches are used in preference to photographs, because the actinic values of the different parts of the arc, and hence the relative photographic effects, are not in proportion to the light values, and it is impossible to prevent over-exposure of the bright parts of the arc when an attempt is made to obtain any details of those parts which are not so bright. The result is that a photograph gives an entirely false record. If a dark green glass and a dark red glass, for example, be fastened together and the arc observed through the combination, a much more true record can be obtained by sketching what is seen. The non-luminous envelope of soot surrounding the arc, the reflection in the pool of slag, and the variation in the brilliancy of the arc from end to end can be well shown. When viewed through such a combination

glass, an arc may be luminous for a time over its entire length, though it appears to be hollow and brighter near one end. If now a second combination glass be added to the first one, cutting off much of the light, the entire arc apparently changes its shape; the electrodes and the less luminous parts of the arc disappear, the luminous portion of the arc grows smaller, retreating toward the negative electrode, and the envelope of soot (being non-luminous) disappears. A third glass will cause a still further decrease in the area of apparently luminous arc; at the same time the reflection in the pool of slag still persists, showing that it must be very bright. That the external envelope of soot which surrounds the arc is non-luminous and only shines by reflected light is also shown by the fact that when burning the arc bright end down, it is seen to be no brighter than the soot which hangs from the upper electrode when equally close to the bright portion of the arc.

The arc, when viewed through the colored glasses, is at all times seen to be practically non-luminous in the center, from end to end. The light comes almost entirely from a hollow cone-shaped area, brightest at the tip, which is in contact with the negative electrode. The reflection in the pool of slag appears to be about two-thirds as bright as this brightest portion.

As stated above, much development work has been done on the electrodes, and it has been very evident that the candle-power is affected by a number of factors. The proportion of surface of the arc that is luminous, of course, affects the quantity of light emitted, but the intensity may also be changed; thus, an arc may be luminous over a larger part of its length, yet not give as much light as another of higher intensity but having a smaller bright area.

The composition of the electrodes obviously has much to do with the light of the arc. For example, there are materials which diminish the light given off by the titanium oxide. There are also materials which act toward the metallic arc somewhat in the same manner as cerium oxide acts toward thorium oxide in the familiar incandescent gas mantle; they apparently cause the titanium oxide to give more light without being light-givers themselves. This warrants the hope that the improvement in the candle-power per watt which has been recently effected in these electrodes will be followed in the near future by even better results.

WELFARE WORK OF A LARGE MANUFACTURING COMPANY

HAMILTON A. ROGERS
Superintendent, Westinghouse Electric & Mfg. Company Relief Department

THE twentieth century marks an epoch in the history of industrial development. The industries are now carrying on their work in a better, quicker and more efficient manner than ever before. The life of the individual also is on a higher, bigger, better and broader plane than has hitherto been possible. While heretofore in many instances the contest for supremacy has so absorbed the attention of the managers of these industries that, in general, the welfare of the employee has practically been overlooked, to-day industrial concerns are everywhere commencing to recognize the result of this imperfect development and are earnestly interesting themselves in the well-being and contentment of their employees.

The thousands of names which appear on the pay rolls of any one of our large industries make it impossible for the person in immediate charge to acquaint himself with the needs of each employee—hence, the necessity of organization. Recognizing this feature in the problem, a solution in a particular case was reached about ten years ago by Mr. E. M. Herr, president of the Westinghouse Electric & Mfg. Company, but who, at the time was general manager of the Westinghouse Air Brake Company. He developed an organization that was one of the first "Relief Departments" of consequence among industrial concerns in this country. This new department immediately became popular with the workmen and its success was phenomenal from the start.

Seven years ago Mr. Herr severed his connection with the Air Brake Company, to accept the position of first vice president of the Electric Company. After becoming acquainted with the situation he took steps to organize a relief department for the Electric Company along lines similar to the one operated by the Air Brake Company. The success attained by the older organization was soon duplicated at the Electric Company.

Notwithstanding the fact that membership is purely voluntary on the part of the employee, the popularity of the relief department cannot be more substantially presented than by referring to the present membership, which is nearly 85 percent of the number of

male employees. This is an exceptionally high mark, considering the fact that men over fifty years of age are not admitted to full membership, and also that some cannot pass the requirements of medical examination, while others, who prefer outside insurance, take the position that they are sufficiently well protected and see no advantage in joining the relief department. It is aimed to make the methods of the department helpful and ambitious; so that they cannot be overlooked in even a casual discussion concerning the welfare of the employees. Its officers are progressive and always on the alert for improvement.



VIEW IN SUPERINTENDENT'S OFFICE
General headquarters of relief department.

The Company has provided commodious quarters for carrying on the work. The superintendent's office is fitted up with all the necessary equipment required to handle the large volume of business of the department. The filing system is efficient and comprehensive. The records of each individual member are kept in a separate file, and through the numbering system all information concerning a member naturally finds its way to the proper place in the files. When a member leaves, his file is kept intact, and in case he returns to the Company's service and wants to be reinstated, his membership is carried on his old number.

The office of the medical director, where prospective members are examined and where any employee is given attention by the medical attendants in cases of sickness or accident, is a spacious and well lighted room, fitted up with the latest improved facilities for the work. The surgical instrument case is supplied with all implements necessary for such work. Two large medicine cases contain various materials and drugs which may be needed to relieve minor illnesses of almost any nature. A powerful magnet has been installed for use in removing pieces of steel or iron which may accidentally become imbedded in the eye or other parts of the body. There are rest rooms for sick men and women. These rooms are provided with cots, stands and lavatories, and are finished through-



RECORD FILE CASES

Complete information regarding some 10,000 names is systematically filed so that details regarding any one is accessible at a moment's notice.

out in white enamel. An electric ambulance is ready at a moment's notice to convey the sick and injured to their homes, or if need be to the hospital.

Employees working in dangerous places where, for example, there is possibility of electric shock, are given instruction in theory and practice in the art of artificial respiration by the prone pressure method. Classes assemble in the medical director's office at 3.30 P. M. daily for this instruction, and when found competent are given a certificate of proficiency in resuscitation from electric shock. As a result of this plan men are available in every part of the works who are ready to act at a moment's notice in case some fellow workman has had the misfortune to receive a serious electric shock. Cases of electric shock are fortunately, however, of only rare oc-

currence. Medicine cabinets containing simple remedies are installed throughout the factory, especially in places where women are employed on test floors, with remedies to be used in case of electric shock to supplement artificial respiration. The dressing of injuries by the foreman or other employees is not recommended. No matter how slight the injury, it is the practice to rush the patient to the relief department.

ORGANIZATION

The relief department is a department of the Company's service in the executive charge of a superintendent appointed by the



MEDICAL DIRECTOR'S HEADQUARTERS

Where sick and accident cases are handled, and where prospective members receive medical examination. View showing part of equipment.

vice president in charge of manufacturing, and whose directions in carrying out its regulations are to be complied with, subject to control of the vice president, except in such matters as are under the control of the advisory committee.

OBJECT

The object of the department is the establishment and management of a fund to be known as the "relief fund" for the payment of definite amounts to employees contributing thereto. The Company guarantees the fulfillment of its obligations; takes charge of all moneys belonging to the fund and is responsible for its safe

keeping; pays into the fund interest at the rate of four percent per annum on monthly balances in its hands; supplies the necessary facilities for conducting the business of the department and pays the operating expenses.

THE ADVISORY COMMITTEE

The advisory committee consists of fourteen members and a chairman. The vice president is ex-officio a member and chairman of the committee, which is chosen annually in December to serve one year from the first day of January next succeeding. One-half of the members are appointed by the vice president and one-half elected by employees who are members of the relief department from among themselves on the basis of membership in the different



MEDICAL DIRECTOR'S HEADQUARTERS
Another view showing medicine case and other equipment, including magnet.

sections of the works, according to a schedule fixed by the regulations. The superintendent acts as ex-officio secretary of the committee, which meets quarterly on call of the chairman, when reports of the department's business are presented and subjects pertaining to its operations are discussed. The committee members consult with the superintendent in regard to matters concerning members of their districts; take up questions concerning disputed claims; present appeals from the superintendent's ruling at the quarterly meetings, their principal aim, however, being to keep in touch with the members in their district and see that all are satisfied. Their efforts in this direction have proven very successful.

THE SUPERINTENDENT

The superintendent has charge of all business pertaining to the department. He employs such clerks and other assistants as are required, subject to the approval of the vice president, prescribes the forms and blanks to be used, certifies all bills and pay rolls of the department, signs all warrants for payment of benefits, furnishes to the committee such reports as they may require, and decides all questions properly referred to him, interprets the rules, and if he cannot satisfy the claimant, it is then entirely within the scope and the duty of the advisory committee to act upon any rule that may admit of more than one plain construction.

THE MEDICAL DIVISION

The medical staff consists of a medical director and one or more assistants, according to the requirements of the work. The medical director has general supervision of the medical and surgical affairs of the department, subject to the approval and the control of the superintendent. The medical division of the department at present consists of the medical director and two assistants, one of these assistants being on duty with the medical director during the day and the other at night. There is thus a doctor on hand at all times, ready for quick action in emergency cases. The introduction of the night doctor is a recent idea, and the thought has proven a wise one, and one which is appreciated by the workmen, as results have shown. A large night turn works in the factory, and the men are pleased to have quick attention in case of injury. Under the old method, an outside physician would be called in, half an hour sometimes being consumed in bringing one to the scene of action.



ONE OF THE REST ROOMS

MEMBERSHIP

There are five classes in which an employee may become a member. This is determined by the finding of the physical exam-

inations, and by the amount of his average monthly earnings. Any male employee not over fifty years of age may, upon passing a satisfactory physical examination and upon approval of his application by the superintendent, become a member in the highest class allowed by his pay, or he may enter any lower class. In case an applicant for membership should be rejected on account of age, or any other just cause, he is eligible for partial membership under accident protection only, on recommendation of the medical director and approval of the superintendent. He contributes half the regular rates for full membership in the first class and is eligible for full rates for accident disability or death benefits resulting from accidental injuries.

While female employees are not admitted as members of the relief department it must not be construed that they are neglected in any way; to the contrary, they are cared for just as though they were members. Matrons are employed to look after their welfare. They receive free medical attention and everything practicable is done to make working conditions satisfactory. They do not contribute to the fund and therefore cannot participate in the distribution of benefits.

CONTRIBUTIONS

Contributions for full membership are made monthly at the following rates:—

1st class,	earning	less than $45.00 per month	$0.50
2nd "	"	$45 to $60 per month	0.75
3rd "	"	$60 to $75 " "	1.00
4th "	"	$75 to $95 " "	1.25
5th "	"	$95 & over " "	1.50

BENEFITS

A member is entitled to receive benefits continuously for thirty-nine weeks for any disability caused by accident or sickness as allowed by the regulations or caused by a succession or a combination of accidents and sicknesses. The following benefits are paid to members or beneficiaries entitled thereto, except for the first week of disability which is classed as due to sickness:—

	Weekly Benefits Sickness	Accident	Death Benefits
First Class	$5.50	6.00	$100.00
Second "	8.25	9.00	125.00
Third "	11.00	12.00	150.00
Fourth "	13.75	15.00	150.00
Fifth "	16.50	18.00	150.00

Accident benefits are paid to members whether injury occurs on or off the Company's premises. In addition to the death benefit

mentioned above, the Company pays a like amount as a gratuity upon the death of an employee who is a member of the relief department.

FINANCIAL VALUE TO MEMBERS

In order to judge the financial value of the relief department to the members, attention is called to the amount distributed among the members for benefits during the year ended December 31st, 1911, viz., $31 270.38, of which $17 935.45 was paid for sick benefits, $10 409.93 for accident benefits, and $2 925.00 for death benefits to the heirs of the deceased members. To more substantially present the financial value of the plan, attention is called to the fact that the amount distributed among the members during the five years of the department's existence is a total of $110 202.57, of which $60 073.19 was paid for sick benefits, $38 654.38 for accident benefits and $11 475.00 for death benefits distributed among the legal heirs of deceased members. There is at present a very substantial surplus in the department's treasury.

The importance of the work done in the medical division should not be overlooked. Thousands of sick and injury cases are skillfully treated each year. The medical director and his assistants are up-to-date physicians and surgeons and by prompt and efficient work many eyes, hands and fingers are saved. Prompt treatment of minor sick and injury cases prevent many probable long sieges of disability, thus saving much loss of time for the workman.

In addition to this work in the relief department, the manager of works and his assistants are earnestly working along lines of sanitation and accident prevention. Safety appliances are being placed on machines, and this work has resulted in a marked decrease in the number of serious accidents reported. Ventilation is being improved; also an improved sanitary drinking water system is about to be installed.

The relief department is the pulse of an army of workers. Its superintendent and medical attendants are continually meeting large numbers of employees and are hence in a position to judge the feeling and attitude of the workmen. It can safely be said that the welfare work being done by the Company is greatly appreciated by the employees and that a general spirit of contentment prevails.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, Box 911, Pittsburgh, Pa.

701—**Resistances in Parallel**—Given 12 wires each of one ohm resistance, connected together so as to form the outline of a cube, as shown in Fig. 701(a); what is the resistance between points diagonally opposite? Please give proof as well as answer. L.T.

The resistance of cube from *B* to *A* is five-sixth ohm. From reasons of symmetry the drop in *1*, *2* and *3* will be the same, making their terminals of the same potential, and their resistances may be regarded as

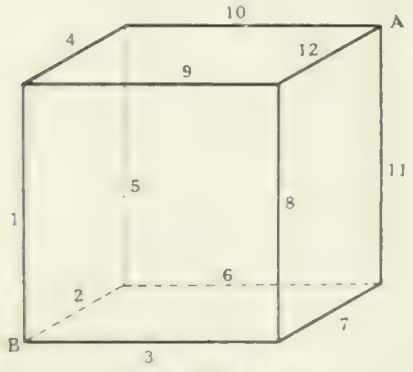


Fig. 701 (a)

in parallel and so equal to one-third ohm. Similarly *10*, *11* and *12* in parallel have one-third ohm resistance; and again the six resistances *4*, *5*, *6*, *7*, *8* and *9* each have their terminals at same potential and the joint resistance is therefore one-sixth ohm, thus making a total resistance of five-sixth ohm. N.S.

702—**Connections of Arc Light Compensator**—Please give method of connecting a 60 cycle 7.5 ampere, four-light, 440 volt compensator on a three-phase 480 volt circuit. J.A.K.

In using the arc light compensator on a three-phase circuit, the primary, or 440 volt side, is simply connected across any one of the three phases in the same manner that it would be connected to a single-phase circuit. The compensator is simply an auto-transformer having enough turns in the winding to make it suitable for 440 volts, 60 cycles, and suitable taps are brought out to divide

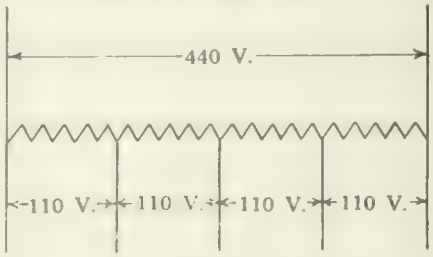


Fig. 702 (a)

the winding into four equal sections, each of which would then have a voltage of one-quarter of the primary voltage. The arrangement is shown in the diagram, Fig. 702 (a). A.P.B.

703—**Boosters for Three-Phase Circuit**—To boost a three-phase system should two or three boosters be used? Please show voltage vectors for both cases. J.C.H.

Either two or three boosters may be used. With a step type regulator giving good regulation, i. e., small

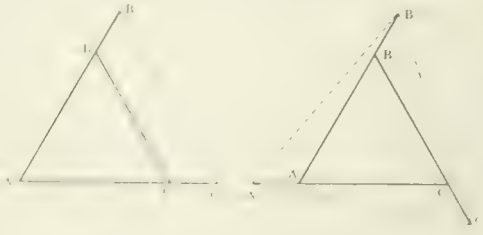


Fig. 703

voltage drop with increase in load, two regulators would probably give good results. With induction type regulators, which have somewhat poorer regulation, three would probably be needed. Fig. 703 (a) shows the vector relations of the voltages with two boosters, in which *ABC* represent the line voltages of the respective phases and *AB'C'* represent the booster voltages. A corresponding vector diagram for

three boosters is shown in Fig. 703 (b). E.E.L.

704—Area of Magnetic Path—How is the area of cross-section of the required magnetic circuit to produce a given induction calculated? C.E.B.

The cross-section of the required magnetic circuit to produce a given induction for an alternating current transformer can be calculated by the following formula:—

$$A = \frac{V \times 10^8}{4.44\, B\, N\, f}$$

In which A = cross-section of magnetic circuit in square inches, V = voltage, N = number of turns, B = induction in lines per sq. inch, f = frequency in cycles per second. In this connection see "Notes on the Design of Transformers," in the JOURNAL for Jan., 1912, p. 94. J.F.P.

705—Connection for Induction Regulator with Relay Control—Please give diagram of connections for an induction regulator, including the connections for the auxiliary relay, voltage relay, and the two resistances. W.A.C.

A diagram of connections of the main and auxiliary circuits of a motor-operated induction regulator controlled by means of primary and secondary voltage regulating relays is given in Fig. 3 of an article on "Voltage Regulating Relays" in the JOURNAL for October, 1909, p. 637. This diagram will give an idea of the method of operating such apparatus. If this diagram is not found to be applicable to your apparatus we would suggest that you make inquiry of the manufacturers giving name plate rating of regulator, serial number, and other facts which have a bearing on the case in question. E.R.S.

706—Details of Monocyclic or Teaser System—Please explain the winding of a single-phase generator for a monocyclic or teaser system, such as is referred to in the JOURNAL for October, 1908, p. 605. What would be necessary to change the single-phase winding to a regular three-phase winding, without changing the sections of the teaser distribution system? L.Y.S.

In the monocyclic generator, which was developed before the three-phase system came into general use to enable polyphase motors to be run from a system primarily designed for single-phase lighting load, the winding consisted of two sections; a main concentrated single-phase winding, and an auxiliary or teaser winding. The latter is designed to generate about one-fourth the voltage of the main winding and is wound in slots situated midway between those occupied by the main coils, as shown in Fig. 706(a). One end is then connected to the middle of the main winding and the other brought out from the machine with the main leads. The relations between the voltages are shown in Fig. 706 (b), *ab* being the voltage produced by the teaser winding and being one-fourth that of the main winding *AB*, which represents the voltage between the main wires, while *Ab* and *bB* represent respec-



(a) (b)

Fig. 706

tively that between the outer wires and the teaser wire. By connecting two transformers in series across the main wires and their common point to the teaser wire, and making a similar connection on the secondary side of the transformers, with the exception that one secondary should be reversed, approximately a three-phase system will be obtained, with secondary voltages represented by *Ab*, *bC* and *CA*. As stated above, these machines had concentrated windings, and as a rule only one main slot per pole, so that it would be impossible to change to a regular three-phase winding. R.W.T.

707—Wattmeter Readings on Six-Phase Converter Circuit—A rotary converter connected diametrically is the equivalent of three single-phase systems, and connected double delta is the equivalent of two three-phase systems. The total volt-amperes, in the first case, is the sum of the volt-amperes of the three phases and in

the second case is the sum of the volt-amperes of the two three-phase systems. Should the wattmeters in the diametrically connected rotary all read positive and their readings be added to give the total power; if so, why? Also in the double delta connections, do the same conditions regarding the wattmeters hold as in any three-phase system, and why? What will be the power-factor in each case? How should a power-factor meter be connected, and how can it be told whether the connection is right or not? S.L.H.

With a diametrical connection, if three single-phase indicating wattmeters are connected, one to indicate the load on each power transformer, all the meters must have a positive reading unless the power is reversed in one or two of the transformers. Such a reversal would not be likely to occur unless the primary voltage was badly unbalanced. The sum of all the readings gives the total power, because the total power is the sum of the three parts received from the three transformers. If one of the wattmeters indicates negative power, the numerical value of its reading should be subtracted from the sum of the other two readings. With a double-delta connection each delta is a distinct three-phase circuit; and, of course, one polyphase or two single-phase wattmeters and a polyphase power-factor meter may be connected to each delta, the same as to any other three-phase circuit. In the article on "Reversed V and Y Connections," in the JOURNAL for Nov., 1911, Figs. 9 and 10 show how transformers may be connected so that only one polyphase wattmeter or power-factor meter is required for both deltas of the double-delta, or for the three power transformers of the diametrical circuit. The wattmeter must in either of these cases have a current capacity greater than the secondary current of a single transformer. See also "Meter and Relay Connections," March, 1909, pp. 172-181. Figs. 1 and 8 of this article give the connections for a polyphase power-factor meter. See also article in the Dec., 1908, issue, pp. 720-30 for additional information on power-factor meters. H.W.B.

708—Half Voltage Taps on Three-Phase Transformers—A 300 kw, three phase, 6600 to 250 and 125 volt transformer is delta connected on both sides. Taps are brought out at the middle point of the low-tension winding in order to get 125 volts, as shown in Fig. 708 (a). What would be the maximum allowable current per phase in the 125 volt line, assuming that the transformer is rated at 300 kw at 100 percent power-factor, and that no current is taken at 250 volts? How is the current in the 125 volt circuit calculated? Are the current outputs of this transformer similar to what would be obtained with three single-phase transformers having two low-tension windings, by means of which twice the current can be taken off at half the voltage by putting the two halves of the winding in multiple? R.F.H.

The current from the line has two circuits: viz., for phase *AB*, Fig. 708 (a), one circuit *A1B* having an



(a) (b)

Fig. 708

impedance Z, and a second circuit *A3C2B* having an impedance 2Z. Likewise, phases *BC* and *CA* have one circuit with an impedance Z, and one with an impedance 2Z. The currents will divide in the circuits inversely as their impedances. Therefore the current in the winding between *A* and *B* = 2/3 current in phase *AB* × ⅓ current in phase *BC* + 1/3 current in phase *CA*. The current in the different phases must be added in proper phase relation, as shown by Fig. 708 (b), and is equal to the phase current. The current in the line is √3 times the current in the winding. The winding of a 300 k.v.a., three-phase, 250 volt, delta connected transformer is designed for a normal current of 300 ÷ (3 × 250) = 400 amperes. When

the load is taken from the middle point of the delta at 125 volts, the maximum current in the line = $\sqrt{3} \times 400 = 692$ amperes, which corresponds to $125 \times 692 \times \sqrt{3} = 150$ k.v.a. Evidently the maximum current in the line is the same for 125 volts taken from the middle point as it is for 250 volts taken from the corners of the delta. J.F.P.

709—Copper Wire Used as Fuse—What sizes of copper wire should be used in an emergency in place of the standard capacities of enclosed fuses. Consider break distance to be about three to four inches, and open to the air. R.D.C.

Copper wire should not be used in place of any enclosed fuses. A supply of extra fuses should always be kept on hand to meet emergencies. The copper wires which are equivalent to standard capacities are as follows:

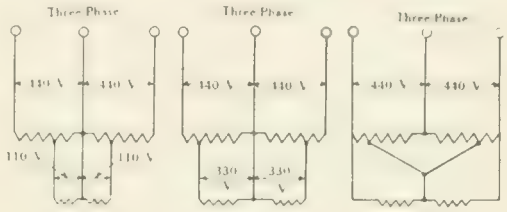
Amp.	B & S Size Wire.
30	19
60	15
100	11
200	10
400	7

The objections to using a copper wire are:

1—That such use would not be approved by the Underwriters due to the severe flash when the wire melts, to not being enclosed in a cabinet and to the possibility of fusing for greater current than the capacity of the fuse block; 2—Proper contact would not be made; 3—The wire may melt first in the holder and injure or destroy it; 4—The arc may maintain itself, destroying the holders and block, and even set fire to any surrounding combustible material. G.S.C.

710—Auto vs. Shunt Transformers for Portable Meters—Which are the better transformers to use with portable meters, auto or straight shunt, transformers? If auto-transformers are applicable, is it not advisable to mark them as such? W.S.D.

Auto-transformers have the slight advantage of lesser weight, compared with transformers having separate primary and secondary windings. Whenever they are used, they should be clearly marked as such, and the connections from the terminals to the windings indicated by a diagram, so as to prevent applying over-voltages to the meters due to incorrect connections, especially on polyphase systems. Fig. 710 (a) is an example of two auto-transformers properly connected to a 440 volt, three-phase system and to two meters having 110 volt windings. Fig. 710 (b) is an example of an incorrect connection which might be made with auto-transformers. In-



(a) (b) (c)

Fig. 710

stead of 110 volts, 330 volts are applied to the meters. Fig. 710 (c) is an example of another incorrect connection causing a short-circuit of the transformer windings. The best practice is to use transformers with separate windings instead of auto-transformers. P.M.

711—Lightning Arrester Protection for Local Circuits—On yard lines of isolated plants is it customary to protect transformers with lightning arrester; for example, on a 220 volt circuit with approximately 1 000 feet of pole line? J.C.B.

It is not customary since 110 and 220 volt circuits are usually too short to be subject to trouble. If as long as 2 000 feet, however, and exposed also, the use of a simple non-arcing, metal arrester of one gap to ground would be helpful. R.P.J.

712—33 000 vs. 10 000 Volt Transformers for Transmission Line—On a 23 mile, 33 000 volt, three-phase line transmitting 1 000 kw, a sub-station is to be located two or three miles from the load to step down to 10 000 volts. A short branch line will also be connected near this point. The first five

miles of line is No. 8 hard drawn copper wire; the next 15, No. 6, and the remainder No. 4, the larger sizes being employed for strength due to ice during the winter. Will it be cheaper to operate at 33 000 volts to all points, using step-down transformers to 220 and 440, or will it be better to put in a sub-station stepping down to 10 000 and then to 440 and 220 at each place of consumption? At present only 10 000 volts is used on the line, but later the 33 000 volts will be used. The sub-station will be placed in the section where the No. 4 copper is used, so that the line loss will be a minimum even if 10 000 volts is used. Will 33 000 volt transformers be cheaper than the 10 000 volt transformers, taking into account the loss due to drop of voltage over part of the line. Please suggest books on the economics of electrical transmission of power over long distances?

F.P.M.

Transformers for 10 000 volts are cheaper than 33 000 volt units; however, it would be better to use 11 000 volt transformers as this is a standard voltage. As the distance to be fed is not over three miles, we would suggest that the current be stepped down from 33 000 volts to 2 200 volts for distribution from the sub-station, as this lower voltage will allow of the use of cheaper line insulation, and is better than distributing at 10 000 volts to consumers' premises. This voltage makes feasible direct distribution without transformers at the load, as standard motors are obtainable for operation directly on 2 200 volts. See answer to No. 465. We suggest the following books: "Long Distant Electric Power Transmission," by Hutchinson ($2.00, net); "Transmission of Water Power," by Adams ($3.00, net); "Alternating-Current Machinery," by Sheldon and Mason ($2.50,net).

A.B.C.

713 — Unbalancing on Induction Motor Circuit—A switchboard panel controls a 200 hp. 2 200 volt, three-phase induction motor, direct-connected to a centrifugal pump. This motor receives current from the secondaries of a set of three transformers which are delta-connected on the primary and star-connected on the secondary side, with the neutral grounded. The primaries supply, also, three-phase induction motor and lights for a mill. The voltage between the secondary wires is 3 800. The three secondary lines are run through the switchboard direct to the motor, which is star connected with a grounded neutral. The switchboard contains the ordinary equipment of indicating and recording instruments and their transformers? The switchboard wattmeters are connected, as shown in Fig. 12, p. 49, of the JOURNAL for January, 1909. It is desired to know if the extent of unbalancing, causing flow of current through the grounded neutral will be so great that with the above method of connection, these instruments will not read correctly within two percent, or must they be connected as outlined in "General Conclusions," p. 120, February, 1909, in order to be commercially safe and correct?

C.T.G.

The amount of unbalancing depends on the induction motor. An induction motor of this capacity, built with as great accuracy in all its parts as is the average commercial form machine, will not cause sufficient unbalancing to introduce an error of more than two percent. In fact, the tendency of induction motors is to correct unbalancing (see No. 143). If the voltage were unbalanced another error would be introduced, but such an error would usually be small. The purpose of special connections, as given on pp. 113-121, of the February, 1909, issue, for four-wire circuits, is to avoid inaccuracies due to unbalancing, and these connections should ordinarily be used for accurate measurements on four-wire circuits. An accidental ground within the winding of the machine would have the effect of causing more or less unbalancing, depending on its location relative to the normal neutral point.

H.W.B.&A.M.D.

PERSONALS.

Mr. Guy E. Trip, who since 1897 has been prominently identified with the Stone & Webster interests, was on January 10th elected by the board of directors of the Westinghouse Electric & Mfg. Company, to the position of chairman of the board, in place of the late Mr. Robert Mather.

Mr. A. Schmidt, who acts in a consulting capacity for several of the European Westinghouse Companies, is spending some time at the works of the Electric Company, at East Pittsburg, acquainting himself with the present engineering and manufacturing methods in this country.

Mr. Calvert Townley, assistant to the president of the Westinghouse Electric & Mfg. Company, was married on December 30th, 1911, to Mrs. Mabel McCormick Steele at Memphis, Tenn. Mr. and Mrs. Townley will make their home after February 14th at the Hotel St. Andrew, New York City.

Mr. Frederick L. Hutchinson has been chosen by the Board of Directors of the American Institute of Electrical Engineers as secretary to succeed Mr. Ralph W. Pope, resigned. Mr. Hutchinson has been acting secretary since last summer.

Mr. Philip A. Lange, managing direcor of the British Westinghouse Electric & Mfg. Company, who was for several years manager of works at East Pittsburg, recently spent several weeks in the United States, chiefly at East Pittsburg, studying methods of production, as well as imparting information relative to methods abroad.

Mr. C. E. Stevens, arc lamp engineer of the detail and supply engineering department of the Westinghouse Electric & Mfg. Company, has been transferred to the general engineering department where he is engaged in work in connection with arc lamp installations.

Mr. J. H. Siegfried has resigned as superintendent of the light and power department of the City of Winnipeg, to accept a position as superintendent of power with the Pacific Power & Light Company, with headquarters at Kennewick, Wash., where he will have jurisdiction over all the generating stations, transmission lines and sub-stations of this company in the Yakima, Walla Walla and Columbia River valleys.

Mr. J. R. Bibbins left Chicago recently to act as chief assistant to Bion J. Arnold in his investigation of the electric traction situation at San Francisco.

Dr. Leo H. Baekeland, president of the Bakelite Company, was elected president of the American Institute of Chemical Engineers, at the recent annual meeting in Washington, D. C.

Mr. B. A. Brennan, recently contract manager of The Westinghouse Machine Company, and formerly with the E. P. Allis Company, has been appointed sales manager of the power department of the Bethlehem Steel Company, in charge of gas engine and pumping sales, with headquarters at South Bethlehem, Pa.

Mr. Harve R. Stuart, of the industrial engineering department of the Westinghouse Electric & Mfg. Company, has resigned and accepted the position of assistant chief engineer of the Robbins & Meyer Company, Springfield, Ohio.

Mr. E. C. Reed, chief writer of the Westinghouse Companies' Publishing Department, Manchester, England, has resigned to become sales manager for Messrs. Miles Sykes & Sons, of Calder Works, Sowerby Bridge.

Mr. C. F. Hockley, for the past three years engineer, power department, of the Bethlehem Steel Company, has been appointed superintendent of construction, power department, with headquarters at South Bethlehem. Prior to his present association, Mr. Hockley was identified with The Westinghouse Machine Company, at East Pittsburg.

The *Practical Engineer* for January 15th, 1912, contains a reprint of the article by Dr. Lauffer on "Electrical Accidents and Their Treatment" from the JOURNAL for August, 1911.

The article by Mr. C. E. Clewell on "Factory Lighting Problems" which was published in the JOURNAL, June, 1911, appears in *Industrial Engineering* for January.

Mr. F. W. Contague, upon completing the engineering apprenticeship course with the Westinghouse Electric & Mfg. Company, has taken up work in the arc lamp division of the sales department.

PERSONALS.

Mr. Sidney J. Carr, formerly of the San Francisco district office of the Westinghouse Electric & Mfg. Company, is now associated with the Hawaiian Electric Company, Ltd.

The Southern Engineer for November contains a reprint of the article by Mr. Dreyfus entitled "Steam Turbines for Electric Stations of Moderate Size" from the JOURNAL for September, 1911.

OBITUARIES.

Mr. William W. Young, purchasing agent for the Union Switch & Signal Company, Swissvale, Pa., died at his home in Edgewood Pa., on January 22nd aged 54. Mr. Young was one of the oldest employees of the company in point of service.

Mr. Charles I. Young, of the commercial training department of the Westinghouse Electric & Mfg. Company, died at Pittsburg, on January 6th. Mr. Young had been connected with the Company since 1886, and, due to his pleasing and cheerful personality, had a host of friends among his fellow-workers. Previous to coming to Pittsburg, Mr. Young was for a number of years engineer of the Philadelphia district office. It is planned to publish a review of Mr. Young's life in the next issue of the JOURNAL.

ANNUAL BANQUET A. I. E. E., PITTSBURGH SECTION.

The annual banquet of the Pittsburg Section of the American Institute of Electrical Engineers is to be held at 7 P.M., Saturday, February 17th, in the English Room of the Fort Pitt Hotel. Mr. K. C. Randall, chairman of the local section, is also acting as banquet chairman. Mr. L. A. Osborne, vice-president of the Westinghouse Electric & Mfg. Company, is to act as toastmaster. Mr. Gano Dunn, president of the Institute, will be the guest of honor and principal speaker. Among the other speakers will be Director Arthur A. Hamerschlag, of the Carnegie Technical Schools, and Mr. H. E. Longwell, consulting engineer of The Westinghouse Machine Company.

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EDISON MEDAL FOR 1912.

At the meeting of the Board of Directors of the American Institute of Electrical Engineers, held January 12th, 1912, the Edison Medal Committee reported that the gold Edison Medal for the year 1911 had been awarded to Mr. George Westinghouse "for meritorious achievement in connection with the development of the alternating-current system for light and power." The report was accepted by the board and immediate publication of the award was authorized. The medal will be presented to Mr. Westinghouse at a meeting to be arranged later.

WANTED.

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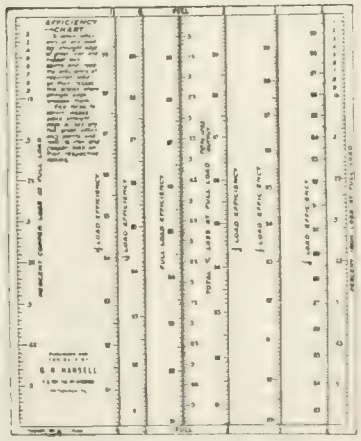
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NEW BOOKS

"Modern American Telephony"—Arthur Bessey Smith; 700 pages, 470 illustrations, hand-book form, flexible leather binding. Published by Frederick J. Drake and Company, Chicago. For sale by THE ELECTRIC JOURNAL. Price, $2.00.

This is a practical hand-book for workers in the telephone field. It should also be of value to others not actively engaged in telephone work who wish to become acquainted with the various types of telephones and the details of the later developments in telephony. About 100 pages are devoted to elementary theory—magnetism, currents resistance, capacity, etc. The various chapters are devoted to transmitters, magnet systems, common battery systems, switchboard installation, testing apparatus, protective devices, measuring instruments, telephone troubles, line construction and wireless telephony. Some 75 pages are devoted to automatic telephone systems. The book is well arranged and thoroughly illustrated with diagrams of connections, views and details of apparatus.

"Hydraulic Turbines — Their Design and Installation"—Viktor Gelpke and A. H. Van Cleve. 293 pages, 200 illustrations. Published by McGraw-Hill Book Company, New York City. Price, $4.00.

Notable installations of water power plants have been completed in this and the preceding decade and their economic value has been the subject of repeated comment and important conferences. Progress in the development of hydro-electric plants has been retarded somewhat recently pending the definite shaping of government policies regarding the control and supervision of water privileges and the right of eminent domain. As soon as the legal aspect is established there will undoubtedly be renewed activity in developing water power resources. Considering that less than ten percent of the 37,000,000 horse-power, economically available in this country, has been installed so far, the future for this branch of engineering is indeed very promising, and it should therefore attract a large number of engineers and students. Thus there is need for treatises which will contain comprehensive information, data and instruction on hydraulic machinery. The present author's book is to be strongly recommended. The position of the authors, Herr Gelpke, a prominent engineer and manufacturer of Germany, and Mr. Van Cleve, formerly consulting engineer to the Niagara Falls Power Company, has enabled them to competently undertake the task. The book is confined to engineering considerations entirely and takes up in three chapters, the details which enter the complete plant;—elements, principles, and the mathematics of hydraulic turbines; and descriptive and pictorial features of many important plants. E. D. D.

"Wireless Telegraphy"—James Erskine-Murray, D.Sc. Third Edition, 1911; 386 pages; 187 diagrams and illustrations; 11 tables. Published by D. Van Nostrand Company, New York City. Price, $3.50.

This is a hand-book covering theory and practice, for the use of electrical engineers, students and operators. The reader is assumed to have a general familiarity with the more common terms related to the subject, yet while the book makes no pretense of being encyclopedic, it presents lucidly the principles and distinctive features of the various telegraphic systems which have been developed—those which have failed as well as those which have lived commercially. A working basis is first established by a brief general review of past research and developments, showing the natural evolution of the present-day systems. Essential apparatus of various types are then discussed, such as those for the production of high frequency currents, and for the detection of wireless electric waves. The explanation of the operation of, and descriptions of the equipments involved in the various systems in commercial use, should be not only most valuable to the student and operator but both instructive and interesting to the layman. The chapter "On Theories of Transmission" aids greatly in making the book distinctive. There is evidence of much care on the part of the author in rendering statements, descriptions and, particularly, quotations authentic. Where mathematics are essential to a full interpretation it is generally paraphrased for the aid of the reader who may not be mathematically disposed. The chapter of practical tables and notes has received special attention in the present revised edition. An interesting feature of the book is the appendix which gives the "Service Regulation" formulated by the International Ratio Telegraphic Convention. E.R.S.

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Tendencies in Central Station Service

Not so very long ago, in the proceedings of the American Institute of Electrical Engineers, a writer prophetically described the conditions when electric energy will be supplied abundantly, efficiently and cheaply through interconnected transmission systems constituting one great network of conductors covering the whole country. He foresaw that this network will be fed by a few large central stations and that hundreds of small central stations will be superseded by sub-stations each supplying a local district with all necessary energy for both light and power.

That prophecy is being fulfilled; the number of central station systems is diminishing while the extent and application of the service is increasing. Small central stations are being absorbed and consolidated into large systems and these systems are being united or interconnected. Central stations are being built and others planned, especially hydro-electric stations, of greater magnitude than any now operating. Notable examples of consolidation and expansion of power companies are those effected in Northern Illinois, California, Colorado, the Carolinas, Georgia, Alabama, Ontario, Canada and others, by such organizations as the Southern Power Company, the H. M. Byllesby Company, etc.

Manifestly, capital in such large amounts is not drawn to these projects until profitable returns are assured. In every case the conditions are carefully and scientifically analized and every possible use for electricity is made the subject of study to determine whether its use can be made profitable. The ideal condition always kept in view is that in which the whole generating and distributing system is continuously employed at or near its maximum capacity. The supplying of energy to widely varying types of load introduces a diversity factor which helps toward attaining this ideal condition.

That ideas and tendencies are changing and enlarging is proven by the fact that central station service is now beginning to be supplied to such industries as steel mills, paper mills, sugar refineries and hat factories, in which isolated plants were formerly consid-

ered a necessity, either on account of the large amount of energy used, or because the steam is required in the manufacturing processes. No industry is now allowed to escape consideration, and many, such as stone quarries, irrigation fields, lumber yards, etc., requiring long extension of lines, are purchasing electric power with economy to both the industry and the central station.

Another most encouraging feature from the engineering standpoint consists of the growing tendency on the part of both central stations and manufacturers of electrical apparatus to study industries carefully with respect to the efficiency of power application without regard to the immediate feature of securing maximum motor sales or sale of current. It is becoming widely recognized that the public service corporations should be what the name signifies and that satisfactory service as well as the number of kilowatt-hours sold is a measure of success.

With the intention of rendering such service, the central station is glad to analize a prospective user's problems and lay before him the details of possible solutions. The comparative merits and demerits of the engine drive with shafts and belts, of group motor drive and individual motor drive, of isolated plant service and central station service, all are set forth in detail from the user's point of view so that he can determine which method will give him the best service. The central station has nothing to fear from such comparisons when they are based on the ultimate effect that each method of drive will have upon the quality and quantity of the finished product and all circumstances are taken into consideration.

D. E. Carpenter

Marketing the Central Station's Output

During the past five years a remarkable change has been brought about in the policy of central station managements in the sale of their output. That a change was necessary was shown by the analysis of competent engineers engaged by various central stations for the purpose of investigating the causes and recommending the remedies for their poor and unpromising financial conditions.

The results of such analysis and investigation invariably indicated that the operating end of the organization was capable, but that the scheme for disposing of the output was bad and in many cases inflicted serious hardship on the operating department by

failing to give consideration to the question of improving the load conditions.

The securing of a daylight motor load naturally recommended itself as a relief, and steps were taken by many companies to get such business, while the more timid ones look on to see the result. The wisdom of this step was quickly proven, and I believe it can be truthfully said that the success of this undertaking has laid the foundation of the "New Business Department" of the modern central station, which has been such an important factor in the rapid and broad development of the industry. The ideal load curve for any central station is naturally one that allows the station to operate at full capacity constantly, and the aim and efforts of the new business department of the central station company are necessarily being directed toward the accomplishment of that end. The organization of a selling force to handle this work properly is very difficult, owing to the scarcity of men trained in the peculiar requirements of the business and the fact that each individual location has many conditions to meet that are not common with other central stations.

Evidently the first work of the new business department should be the securing of that business which is most easily obtained, and with this in view the results of the first canvass of the district in which the company is operating should be carefully studied in order to pick out the most promising prospects upon which to work. In securing quick results in this way the company is making a step toward the reduction of its cost per kilowatt-hour generated and preparing itself for securing business that can only be obtained at lower rates.

At the present time the best results appear to be obtained by dividing the work of the new business organization into five departments; namely, a domestic department, including residence and apartment lighting and power; a commercial department, including stores, offices and office buildings; an industrial power department, including all industrial plants using electric power and heat for manufacturing purposes; an electric sign department, including display signs and decorative lighting, and a municipal department, including municipal, borough and township lighting. The selling departments must ever keep before themselves the vital fact that central station service must have the merits of cheapness, reliability and convenience in order to secure business in competition with gas and isolated plants. In order to show such merits it is obvious that the solicitor must be capable of studying and investigating the condi-

tions of the prospective customer's proposition in an intelligent manner, and be able to submit the facts and arguments for the adoption of his proposition in a clear and forceful way.

The possibilities of the use of central station power for industrial plants are being realized more generally every day. Manufacturers see the advantages of the concentration of the power plant at the point most suitable for the economic production of power on a large scale, and appreciate the greater economy and reliability of purchasing energy to be delivered not only when but where it is to be used, thus enabling them to build their factories to meet the requirements of their processes of production with minimum handling of material.

Much good has been accomplished in the sale of central station service by coöperation between companies throughout the country through the organized efforts of the National Electric Light Association. The rate question is at the present time receiving a great deal of attention and the association is making an investigation for member companies with a view to determining the best basis for a uniform system of rates.

The coöperation of the electrical manufacturing companies has been a great help to the central stations in building up their business and this attitude indicates their confidence in the great future of the central station proposition and its wonderful possibilities.

JOSEPH MCKINLEY

Electricity in Connection With the Panama Canal

It is a fact not generally known that the unit costs of doing the work in nearly every branch of the Panama Canal undertaking are less than has ever before been attained. The magnitude of the proposition has, of course, had a direct bearing on these costs, but it would seem that these might have been more than offset by the difficulties and extra expense due to the location, and climatic conditions under which the work has been carried on. On close analysis it will undoubtedly be found that the low cost has been due entirely to the character and farsightedness of the men who have been entrusted with the organizing and carrying out of the work.

That these men should have adopted electrically driven equipment wherever possible, as pointed out in the article by Mr. Hanker in the present issue of the JOURNAL, because of the great economy of the equipment so driven, is but one of the many evidences

of their foresight. While electricity is being used extensively in the building of the canal, it will be used entirely in operating it, as the plans include a large power house in which hydraulically driven generators will be installed to furnish the curent for the operation of the locks, and numerous other applications for the handling of the traffic through the canal.

With an organization that embraces nearly every branch of human activity, under conditions that seemed almost insurmountable, these men by their discernment and close coöperation, are bringing to completion the greatest engineering achievement of modern times, over a year ahead of the scheduled time—a triumph to American character, efficiency and equipment.

W. K. Dunlap

Increasing the Use of Motor Drive

The statement was recently made by a prominent electrical engineer that only about twenty per cent of the industrial plants in this country are electrically equipped notwithstanding the enormous electrical developments and activities during the past twenty-five years, and the many advantages to be secured by the use of electric drive. This apparently small percentage is due partly to the fact that the growth in new industries and increase in size of others have been so rapid that the central stations, while developing rapidly, have heretofore exerted themselves principally to supply power to those concerns which were compelled to use electricity in order to meet competition and accomplish desired results. It is also due to the fact that not until the last few years have the central stations adopted the policy of educating power users regarding the many direct and incidental advantages of motor drive. Under past conditions it would require many years to increase materially the above percentage. However, with the present rapidly growing activity of power distributing companies, with their energetic commercial departments, this percentage should be very largely exceeded

While the central stations were small and covered only a limited territory, it was commonly necessary for a manufacturer who desired electric power to install an expensive independent generating plant, including duplicate units, to insure continuity of service, in addition to the motor and lighting installation. The cost of the entire equipment was frequently prohibitive. But with the im-

provement in power plant apparatus has come a corresponding assurance of continuous service. Also the consolidation of many of the smaller central stations into larger operating organizations with hundreds of miles of high tension distributing mains has greatly reduced the cost of power generation. Such organizations give small communities, as well as larger cities, the benefit of their larger experience, of high grade commercial and engineering departments and of efficient and reliable power generating and transmitting equipment.

The larger operating companies aim to furnish all the power requirements in their districts and are generally in a position to deliver power at a cost lower than that at which the industrial manufacturer can produce it, either with an isolated plant and electric drive or by the use of steam or gas engines and shaft drive.

With central station service available, the electrical equipment for individual drive, requiring motors only, will cost from one-third to one-half what it formerly did when a generating equipment was necessary. In case of a new plant, motors will cost little if any more than line shafts and heavy belts. In the case of an old plant, with a fairly good power equipment, the salvage from old equipment will go a long ways toward offsetting the cost of motors.

It is quite certain that in all future industrial developments the possibilities of motor drive, using central station service, will be given careful and favorable consideration. This fact, along with the energetic efforts and new business getting methods of the power companies, electrical manufacturers, electrical contractors and supply companies will probably result in greater development in the central station power business within the next five years than has occurred in the past twenty-five years.

One of the commendable features in connection with the growth of the electrical industry is the close co-operation which is being brought about between the central stations, manufacturers and contractors, in educating the power using public through newspaper and magazine advertising, and through personal solicitation. The work of the central station solicitors has been greatly facilitated by the data supplied by the engineers of the various manufacturing concerns and through the commercial section of the National Electric Light Association.

The campaign to extend the use of electric power has even been enlarged to include the general public. One of the recent features of this campaign is seen in the "People's Electrical Page"

published weekly in a dozen or more city dailies, and devoted to items of interest regarding electrical apparatus and its uses. The slogan idea applied to cities is another example which has become popular. Such expressions as "Denver, the City of Light," "Brighter Brooklyn," "Do It for Rochester," "Pittsburgh Promotes Progress," etc., indicate a coöperation between the merchants, manufacturers, boards of trade and central stations to boost their cities which should redound to the commercial advantage of all concerned.

W. B. WILKINSON

A Visit to a Marble Quarry

On a first visit to the works of the Vermont Marble Company at Proctor, Vt., one is impressed with the amount of switchboard and tombstone material available in the stock yard and the amount of sawed marble block which has been used in the several buildings and for flagging around the works. All of this would give an impression of extravagance and luxury were it not that Proctor is in the heart of probably the greatest marble producing section in the world. From Rutland to a number of miles beyond Proctor marble outcrops are frequent and prominent, and at many of these the presence of derricks indicates the existence of quarries.

Teams pass in and out of the many mill doors, dragging blocks of marble on ordinary stone boats. The larger blocks, weighing several tons, are moved on rollers, such as used in moving buildings. In the mills the sawing looks slow and inefficient—the saws advance only about one inch per hour—until it is recalled that ten or fifteen blades in a gang each cut an inch per hour through a block about five or six feet long, which is approximately equivalent to a single saw cutting in halves a marble post six feet long and one foot thick. Row after row of gang saws are at work with no apparent attendance, except that of the driving motors, and a liberal supply of water and sand that constantly runs down over the marble and into the saw cuts.

The amount of sand required for sawing and grinding is remarkable. Several years ago seven teams, each hauling six loads a day, were required to furnish the necessary sand. Now a telpherage system, running for a distance of two and a half miles over a mountain, brings seventy-five 150-pound buckets of sand per hour. This system runs about twenty hours per day, delivering in that time in the vicinity of one hundred tons of sand. All of this is used for grinding and sawing marble. After the sand has been

used at the Proctor works, it is carried in a trough across the river, just back of the mill, to a large plot of low ground, where it is deposited.

The absence of dirt in the quarries is rather striking; marble is practically the only refuse material. Some of the older quarries are blackened by the smoke from steam boilers which were formerly located in them as a source of power. Now electric lights, electric drills, and electric channelers all make for efficiency and comfort.

The quarry openings are not large, but the space underground in some of the old ones is enormous. The ceilings in some places are more than one hundred feet high, and are supported by marble columns comparable with massive bridge piers. In one quarry, about two hundred and fifty feet deep, ice was still unmelted at the end of June. When working in the deep quarries in the summer, the workmen require heavy winter clothing.

The many shades of marble that are found in a single quarry at Rutland are surprising, both in range of colors and in types of marking; dark green, blue and yellow, and many variations running into the pure white, and also combinations of these shades, so that the show room of the marble company is a real art gallery.

K. C. Randall

LARGE SYNCHRONOUS MOTORS FOR COMPRESSOR SERVICE

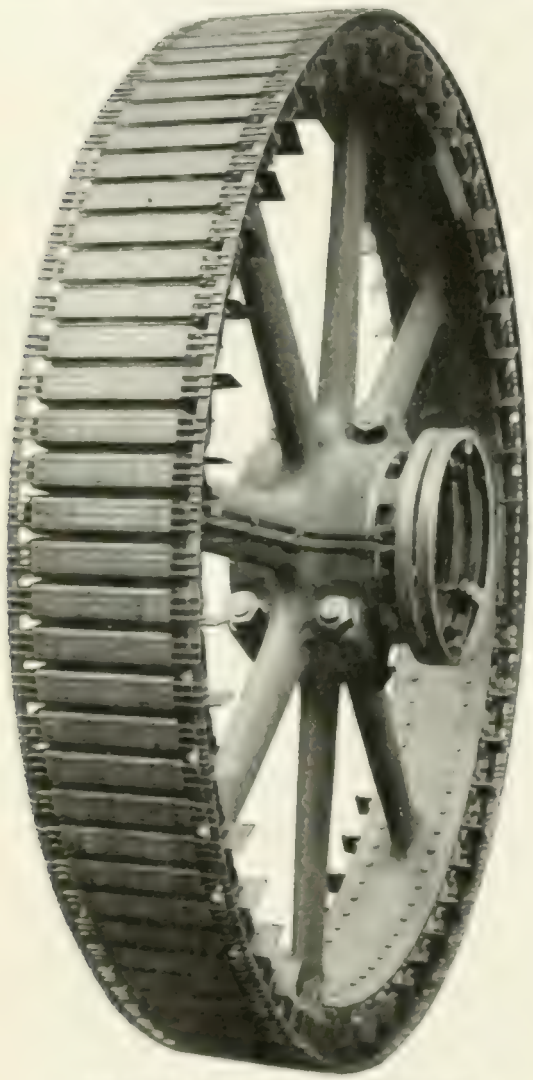
G. B. ROSENBLATT

THE use of compressed air for certain classes of mining operations has been standard practice for a long time. The application of electric drive to the compressors which furnish the air is also by no means new It is, however, only within late years that the advantage of building central air compressor stations has received any great amount of attention from mine operators.

For large individual or separately owned neighboring properties, there are many advantages to be obtained from a centralized air compressor station, some of the most obvious of which are the use of large units with consequent increased efficiency, reduced cost per horse-power installed, minimized cost of attendance and installation, and decreased cost of spare units. Other advantages not so patent are the possible improvement in load factor and the use of a special form of electric drive, both of which tend to reduce the first cost of the installation and the cost of power for its operation. There are, however, many cases where the installation of a central compressor plant is not justifiable. Electricity usually can be transmitted to better advantage than can compressed air which is markedly affected by temperature. The problem as to whether a centralized air compressor plant will prove profitable is one that must be decided for each particular case, but it will be found that the economy of centrallized air compressing machinery can often be proven for cases where the advantages are not apparent on casual inspection. As the policy of centralizing air compressor stations in mining is one worthy of considerable attention, a few words regarding the selection of electrical apparatus for such stations and a description of one of the largest stations in this country may be of interest.

Air compressors for the pressure used in mining work (varying from 60 to 100 pounds) are usually reciprocating in type and compound. They may be driven either by direct-current, induction or synchronous motors. The motors may be connected to the compressors either by gear, belt or rope drive, or mounted directly on the compressor shaft. The use of gear drive for large units is at present not to be recommended, except for very special cases.

Probably for units requiring up to 500 horse-power, belt drive is at present the most popular, and for larger units rope drive has many adherents. The use of direct-connected engine type motors has, for some unexplained reason, not received the attention from mine operators that it deserves. While direct connection necessitates a large slow speed motor with very definite starting characteristics, it will usually be found, when viewing the matter impartially, that for units requiring motors of 350 horse-power or larger, direct connection of the motor to the compressor shaft will prove most economical. The economy may not be apparent in the first cost of the apparatus, but when the cost of foundations and buildings is estimated, when the increased efficiency due to the elimination of the belt or rope is ascertained, and when attendance is considered, it will usually be found that direct connection is best for units of moderate and large size.



SOLID-CASTING TYPE OF ROTOR

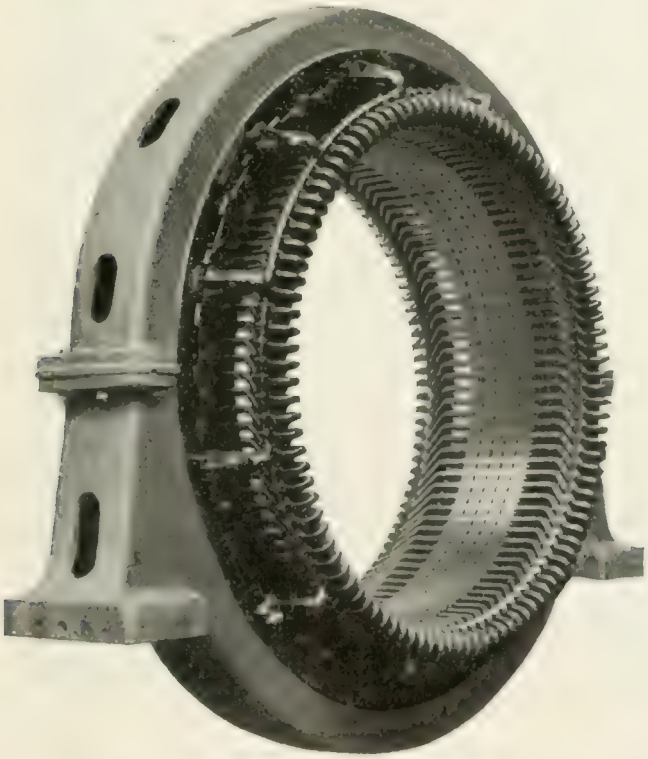
For synchronous motors used by the Anaconda Copper Mining Company at Butte, Montana.

The next point to consider is the type of motor to be used. Except in coal mining and similar plants, where much direct current is used, the source of available power is almost entirely three-phase alternating current at either 25 or 60 cycles, more generally at 60 cycles. Either induction motors or synchronous motors may be selected to drive the compressors. Both types offer particular advantages but the advantages of the synchronous motor are not generally realized. In fact, until recently, the synchronous motor for mining installations has been regarded as something to be avoided. The fact that synchronous motors can be designed with

reasonable self-starting characteristics is not generally known and the fact that a synchronous motor can be designed which will have great stability and will not easily fall out of step is not realized by the many engineers engaged in the mining industry.

The direct-connected induction motor in sizes under consideration is almost invariably of the wound rotor type with slip rings to permit insertion of resistance in the secondary circuit during starting.

The direct-connected synchronous motor for the same conditions is usually of the revolving field type and will be provided with a cage winding on the fields, at least to prevent hunting if not to give self-starting characteristics.



STATOR OF LARGE SYNCHRONOUS MOTOR
Showing the simplicity of construction.

For either type of motor the speeds to meet efficient commercial designs of compressors will vary from approximately 200 to 75 r.p.m. The starting torque required will range from 25 to 40 percent of full-load torque. Constant speed over wide ranges of load or rather the maintenance of normal speed under heavy load, is to be desired.

For such service the two types of motors compare as follows. The induction motor has the distinct advantage that no direct current is required for excitation. It will also exhibit somewhat better starting characteristics in that it will develop the required starting torque with a less draft of current from the supply lines and develop sufficient starting torque even under conditions of low voltage. On the other hand, the synchronous motor can be designed to develop sufficient starting torque for any ordinary compressor, and will have a better efficiency than the corresponding induction motor. The induction motor will probably have a power-factor between 85 to 90 percent lagging at full load, while the power-factor of

the synchronous machine will be unity, or the current may be leading and thus help to improve the power factor on the system to which it is connected. Where power is charged for on a k. v. a. instead of a kw or horse-power basis, this will mean a marked saving in the cost of power for the synchronous motor.

The induction motor will *not* be simpler than the synchronous motor. The stator windings on both machines will be of the same approximate type. The phase wound rotor of the induction motor will be not quite as simple and rugged as the revolving field of the synchronous motor. Both machines will have collector rings, the induction motor three, the synchronous motor only two. The starting device for the synchronous motor will be no more elaborate or complicated than that of the induction motor and the air-gap on the synchronous motor will be decidedly larger than that of the induction motor, a marked point in its favor. The synchronous motor will maintain constant speed under all conditions of load. The induction motor on the other hand will show a falling off in speed practically proportional to the increase in load up to full load, and a somewhat greater falling off in speed above full load. Both motors can be built for a maximum torque which will be well beyond the greatest requirements for the service and the synchronous motor may be given characteristics that will insure its stability or power to "hang on to the line" under abnormal conditions. These two facts are not generally realized by operators. Figures confirming this are given below.

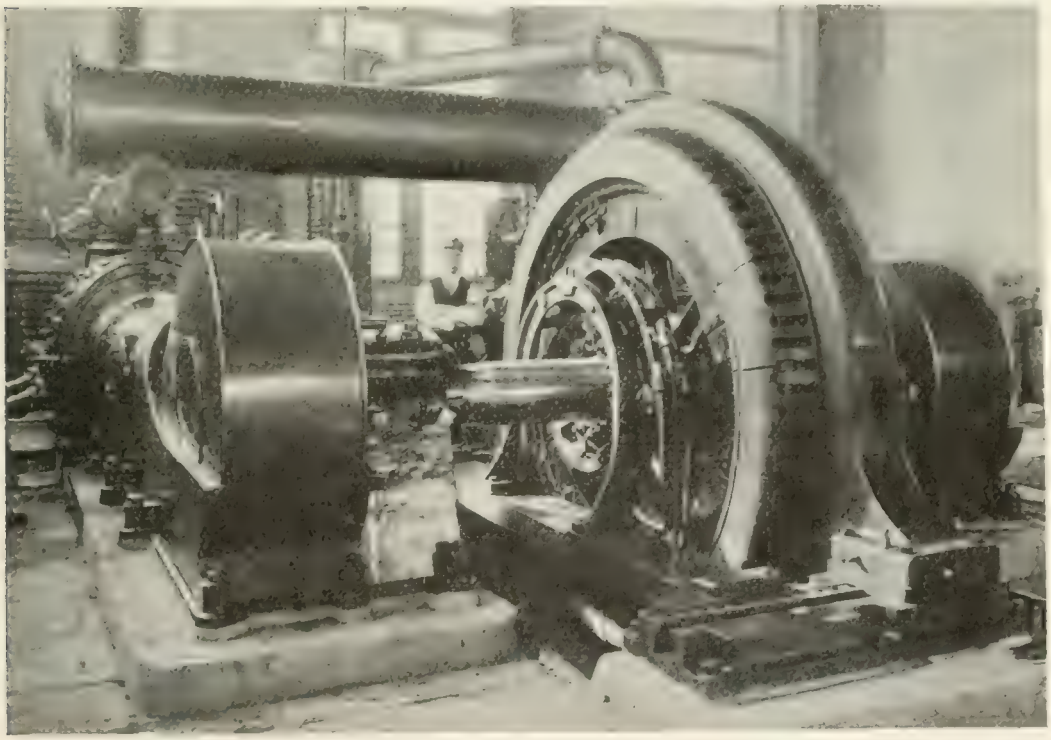
In a plant having several units the disadvantage of having an exciter for the synchronous motors is not so marked as where a single unit is installed, as one exciter may be employed to furnish direct current for a considerable number of synchronous motors.

The starting of either type of machine is equally simple. In either case the compressor is "unloaded" before starting. A self-starting synchronous motor synchronizes itself. If, as is the case in some large plants, the synchronous motor is not self-starting but is brought up to speed by the compressor, with its valves reversed, acting as an air engine or by an auxiliary starting motor, special attention to synchronizing may still be avoided by the use of an automatic synchronizer.

The selection of a proper synchronous motor is not as easy as that of an induction motor. Any induction motor of the proper real capacity, voltage, frequency and speed, with a reasonable pull-

out torque, to carry it through periods of low voltage, and ordinary starting characteristics will operate a compressor successfully, though possibly not as satisfactorily as might be the case with a more carefully designed machine. In selecting a synchronous motor for the same service, a number of features must be born in mind which do not enter into the selection of an induction motor.

The first is the fact that development of the 30 per cent full-load torque usually required at starting, necessitates a power supply of from one and one-half to three times normal full-load k. v. a. A self-starting synchronous motor starts as an induction motor

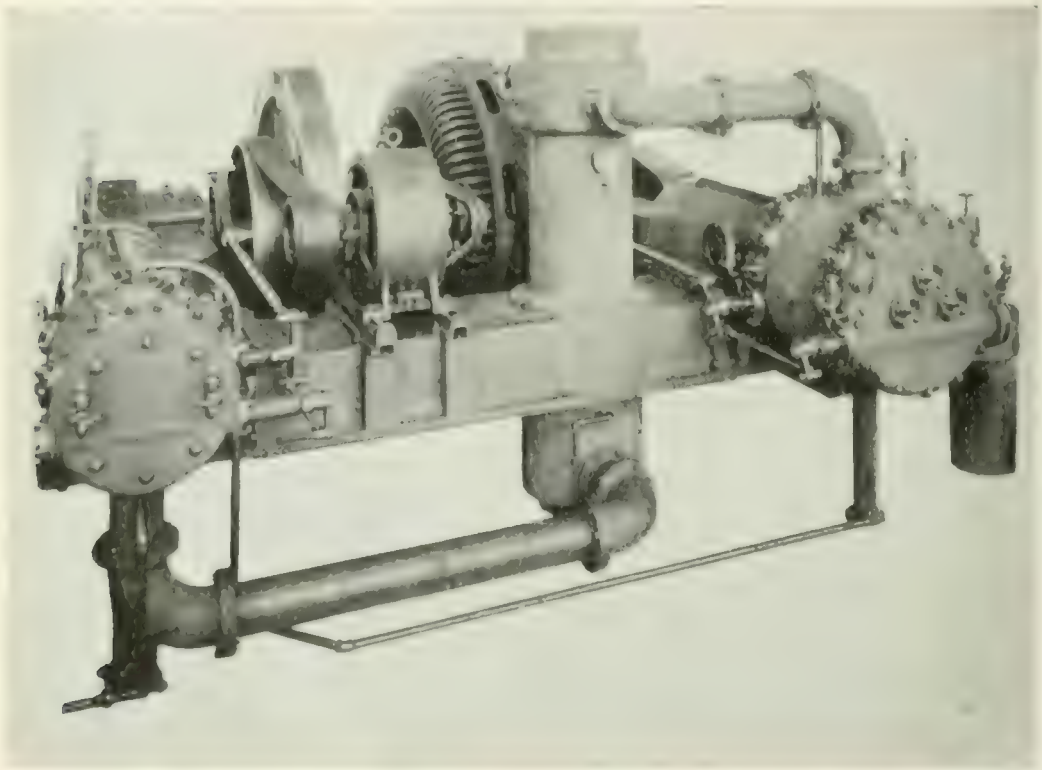


560 HORSE-POWER, THREE-PHASE, 440-VOLT, 120 R.P.M. INDUCTION MOTOR DIRECT CONNECTED TO AN AIR COMPRESSOR
At the Cornwall Ore Banks, Cornwall, Pa.

and at that speed where it changes in action from an induction motor to a synchronous motor the torque suddenly falls to one half or less of the starting value. The value of torque at this point is called the pull-in torque. True the greatest torque is required at starting to bring the parts of the compressor from rest to motion. Thereafter less torque is required to speed them up, but this torque must not be greater than what is termed the "pull-in" torque. Many synchronous motor applications have been unsatisfactory through an oversight of this fact. The starting torque of a self-starting induction motor may be increased by increasing the resistance of

the cage winding, but as this increase in resistance increases the slip of the motor operating as an induction motor, it increases the gap between the maximum speed the motor will attain under load when operating as an induction motor and its synchronous speed, which is its normal speed when operating as a synchronous motor, and the pull-in torque decreases as a result. In a well designed motor the resistance is so proportioned that a good balance between starting and pull-in torque is obtained.

The second is the fact that a certain amount of care must be



400 HORSE-POWER SELF STARTING SYNCHRONOUS MOTOR, 6 600 VOLTS, THREE-PHASE, 60 CYCLES, 187.5 R.P.M.

Direct connected to an air compressor in Central Park, New York City, supplying air for use in building a 16-foot tunnel for the Cat-skill Aqueduct System.

employed in the selection of a proper fly-wheel for use on a compressor to which a synchronous motor is to be direct-connected. The compressor, being a piece of reciprocating machinery driven from a rotating machine, must have a fly-wheel to equalize the uneven efforts required to keep the reciprocating parts in proper motion. In other words, the fly-wheel stores energy through part of each revolution and returns it to the reciprocating parts at other portions of the revolution. The fly-wheel accordingly must generate impulses. In a simple compressor there would be two impulses

per revolution, as a compound compressor unit. These impulses will give the fly-wheel a certain period of oscillation, depending on the amount of the impulses and the weight and radius of gyration of the fly-wheel. Care must be taken that the period of oscillation of the fly-wheel does not coincide too closely with the natural period of oscillation of the motor and the electrical circuit to which it is connected. The reader is not one that requires the correction of the rest of the compressor, but to insure satisfaction to himself he should make certain that the motor has been given overcapacity by the manufacturers of the compressor motor. For a given combination of synchronous motor and compressor there will usually be a considerable number of fly-wheels, differing in weight and diameter whose period of oscillations will be absolutely safe. Some may be too light for the mechanical requirements of the compressors, others may be so heavy that their cost will be exorbitantly high, but there will always remain a considerable number of reasonable dimensions from which a final selection may be made.

As an appendix to the above discussion, a brief outline of what one large plant is practice may be of interest.

The Anaconda Copper Mining Company at Butte, Montana, has for some years pursued the policy of centralizing its air compressors. Four such central compressor plants have been placed in operation and marked economies obtained by so doing. In the three latter plants induction motors with rope drive have been used. The total installed capacity varies from 1700 to 2400 horse-power per plant and the units range in size from 300 to 800 horse-power. For the most modern plant, direct connected synchronous motors were determined upon after careful considerations and the size of individual units increased to 2000 horse-power. Three of the units have now been in successful operation for more than a year. A fourth unit is being installed and two more are to follow, making the ultimate total installed horse-power in this one plant 7000 horse-power, capable of compressing 28 000 cubic feet of air per minute to 90 pounds pressure.

Apart from the size of the units and the use of heavy overspeed, unbalanced motors, this plant is unique in refinements that have been incorporated to maintain a high efficiency and at the same time facilitate the operation. An elaborate governor system is employed, the compressors discharging into large steel cylinders from which the mains leading to the machines carry the air down their supply. The combined capacity of these cylinders is sufficient to carry the load without an

the compressor plant for nearly half an hour. Constant pressure is maintained in these receivers hydraulically, the water in the bottom of the tanks being received from an open water tank on the hillside above the plant, at a sufficient elevation to provide the required pressure of 90 pounds. The entire air contents of the receivers may thus be used at full pressure, and it is impossible under any circumstances to exceed this pressure. The receiver system permits the compressors and the motors driving them to be operated always at full load and maximum efficiency. Large variations in demand are taken care of by starting or stopping an additional compressor unit.

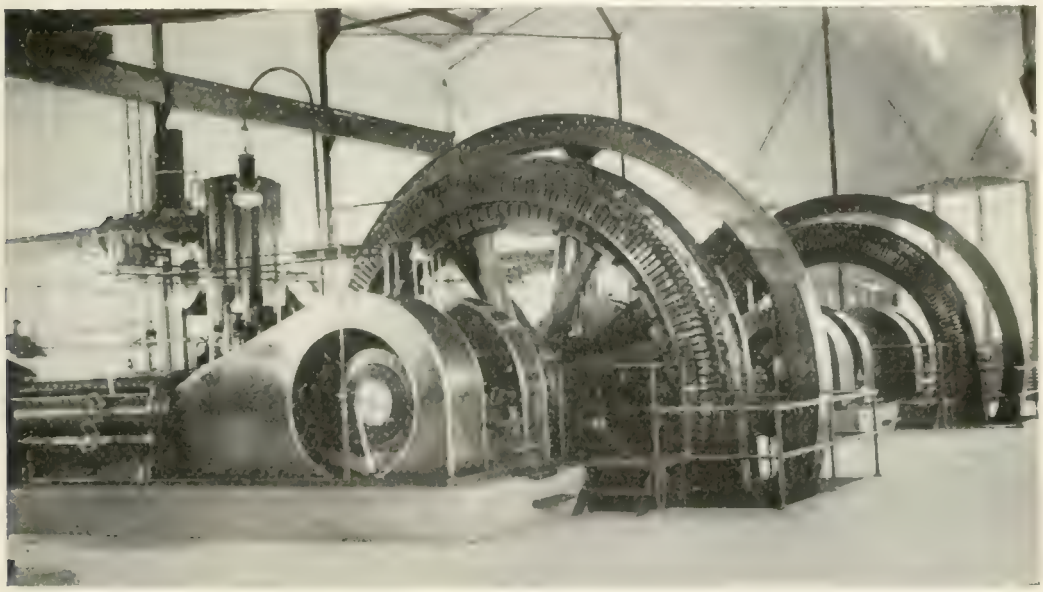
It will be seen, therefore, that in designing this station every benefit that might accrue from the centralization of the compressing machinery has been taken advantage of. The cost of buildings, foundations, machinery and maintenance has been cut down to a minimum per cubit foot of air. Transmission losses between the motor and the compressor have been entirely eliminated. The apparatus is operated at maximum efficiency and the load-factor is so good and the absence of peaks so marked, that the power company can afford to make a marked concession in its charge. Further, the synchronous motors employed in this plant are designed to carry their full normal mechanical load with fields over-excited so as to obtain 80 per cent power-factor leading in the motors. With the entire plant of 7200 horse-power in operation, this feature will permit of enough corrective effect being obtained to greatly compensate for the low power-factor of some 15000 horse-power of induction motors operating elsewhere about the company's properties.

The particular synchronous motors installed at the Anaconda Copper Mining Company's plant are built with squirrel cage windings on the revolving fields. They may in case of necessity be self-started, but are not designed primarily as self-starting motors. As there is almost always some pressure in the receiving system of the compressors, arrangements have been made to reverse the valves on the compressors and permit each one to act as an air engine and bring its motor up to speed, after which the motor is synchronized in the ordinary manner. As a refinement, an automatic synchronizer has been included in the switchboard equipment, permitting the motor to be synchronized without any attention from the operator, when it reaches the proper voltage and speed. Should pressure in the receivers fail, due to some accident, the motors

can still be started by applying alternating current to the armature windings.

As an instance of what can be done in the designing of a synchronous motor of this size as to efficiency and stability, a description of the motors in this plant is presented:—

The motors are all rated normally at 1200 horse-power, three phase, 60 cycles, 2400 volts, 75 r. p. m. They have a continuous over-load capacity permitting their operation at 1500 horse-power and 80 per cent leading power-factor in the motors. They are engine type in construction, the spiders of the revolving fields being in halves assembled directly on the shafts of the compressors. At



VIEW IN COMPRESSOR ROOM OF THE ANACONDA COPPER MINING COMPANY

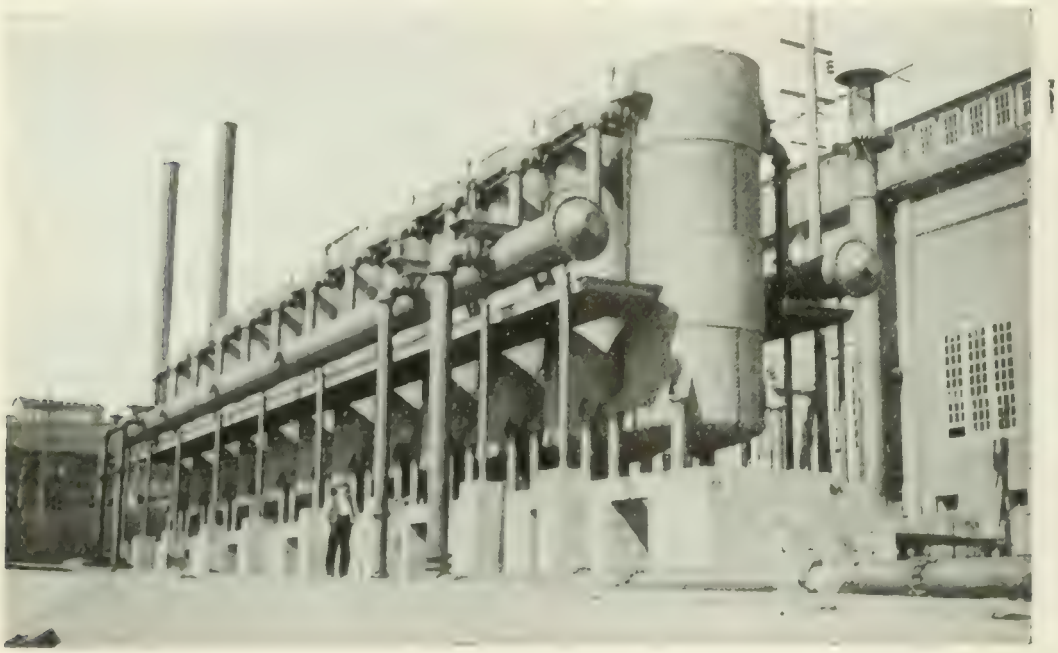
Showing 1 200 horse-power synchronous motors, direct connected to air compressors.

full load they have an efficiency slightly in excess of 95 per cent. A corresponding induction motor designed for a reasonably good power-factor, would not have better than 92 per cent efficiency. Accordingly in this plant of 7200 horse-power, where there is a saving in efficiency of about three per cent or something over 200 horse-power, which when capitalized means a very considerable investment.

The engineers of the Anaconda Copper Mining Company were at first somewhat fearful that these synchronous motors would not be sufficiently stable on the line, particularly if considerable power-factor correction were attempted with them, and accordingly the manufacturers agreed to guarantee successful synchronous opera-

tion without tendency to fall out of step or hunt under conditions of from one-quarter to one and one-quarter load with the voltage varying from 2200 to 2600 volts and at various power-factors ranging from 80 per cent leading to 100 per cent.

A maximum of two and one-half times full-load torque with the motors operating at unity power-factor was also guaranteed. After operating for over a year the motors have proven that they will more than meet the guarantee regarding stability made for them and have proven themselves in every way equal in operation to any induction motors, while allowing a considerable improvement



COMPRESSED AIR ELEVATOR SYSTEM OF THE ANACONDA COPPER MINING COMPANY

in efficiency over what might have been obtained from induction motors, and at the same time permitting of large power-factor correction altogether impossible with induction motors. The determination of the Anaconda Copper Mining Company's engineers to double the output of this plant, using motors of exactly the same design as those now installed is a good testimonial of their satisfactory performance.

INDUSTRIAL MOTOR APPLICATIONS ON THE PANAMA CANAL

F. C. HANKER

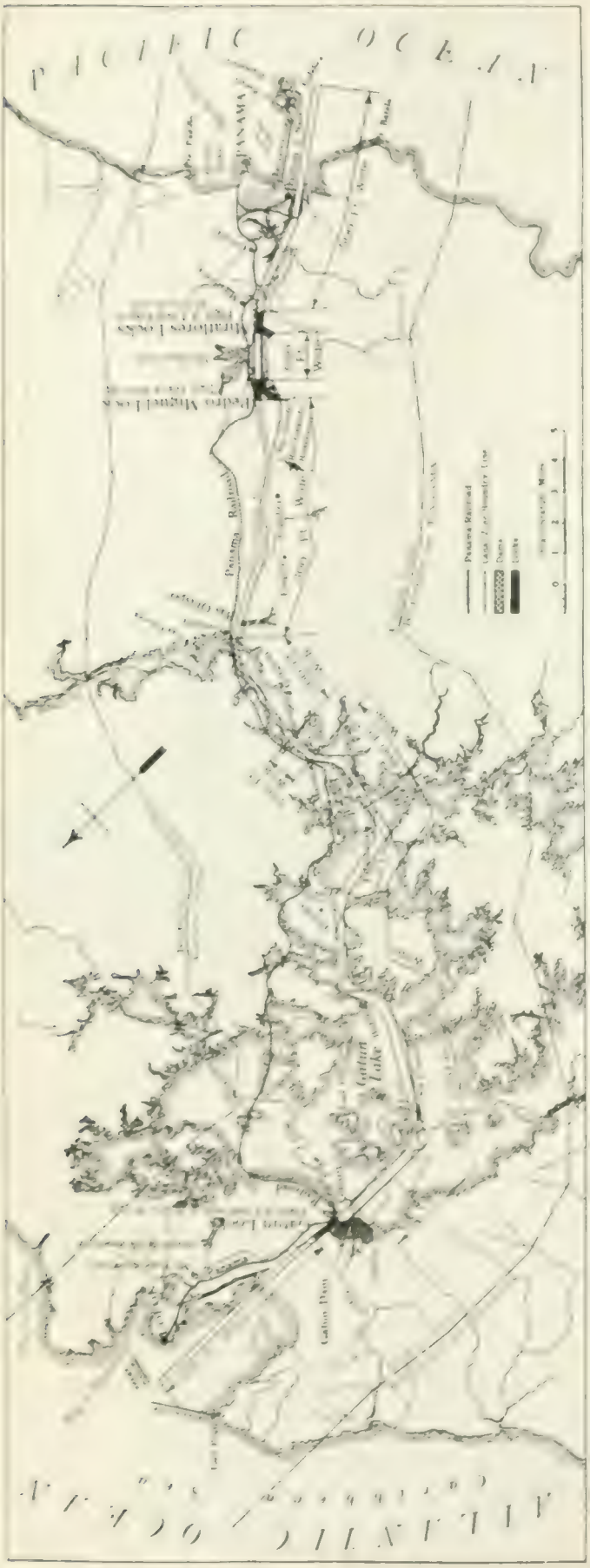
THERE has been so much information published relative to the general type and features of the Panama Canal that it is not necessary to give a detailed description here. As is well known, the canal is of the lock type with three lifts to raise the vessels 85 feet to the level of Gatun Lake.

The future Atlantic or Pacific liner will enter a channel having a bottom width of 500 feet at Port Limon. The ship will steam seven miles through the river-like canal to the locks at Gatun. Here it will enter a series of three locks and be lifted to the level of Gatun Lake. From these locks it will steam at full ocean speed for a distance of 24 miles over a marked channel from 500 to 1000 feet wide across Gatun Lake to Bas Obispo. Here the vessel will enter the Culebra cut and for nine miles will necessarily travel at comparatively slow speed owing to the narrow tortuous channel. the width at the bottom in this section being 300 feet. At Pedro Miguel is a single flight of locks through which the vessel is lowered to Miraflores Lake. The route will extend for a distance of one and one-half miles through this lake to the Miraflores locks. These locks are in two flights and will lower the vessel to sea level on the Pacific side. From this point there will be 8.5 miles of sea level canal to deepwater in the Pacific. As may be seen from the outline map, Fig. 1, it is necessary to go East as well as South to go from the Atlantic to the Pacific when traveling by the canal.

In the construction work on the canal, electrically driven equipment has been used wherever the work has been concentrated to such an extent that it was desirable or economical to employ such motive power. At the Gatun locks and at the locks on the Pacific the character of the work was such that the superiority of electrically driven equipment was unquestionable.

CONSTRUCTION WORK ON THE ATLANTIC DIVISION

The work at Gatun may be separated into two classes, the construction of the dam and the construction of the locks. In the construction of the dam two miniature mountain chains were built of carefully selected rock brought in part from the cut at Culebra. The area between these piles of rock, comprising the hydraulic



SHOWING FINAL WATER LEVEL OF LAKES AND CANAL

core, was filled in by pumping carefully selected material from adjacent sites both above and below the dam. Some of these pipe lines were of considerable length and in them were installed relay pumping outfits, the centrifugal dredging pumps being driven by 550 horse-power, three-phase, 25 cycle, 2 200 volt, squirrel cage induction motors. The dam thus formed is 7 500 feet long, 2 100 feet wide at the base, 400 feet wide at the water surface and 100 wide at the top, which is about 115 feet above sea level. A concrete spillway, constructed through the center of a small hill in the line of the dam, provides for carrying off excess water and for regulating the height of Gatun Lake.

The material used in the construction of the locks is handled by electrically driven equipment from its de-

livery in barges at the harbor excavated in the old French canal to the placing of the concrete in the locks. The crushed rocks is received from the quarries and crushers, located at Porto Bello, about 20 miles east of Colon, and the sand from the sand pits at Nombre de Dios, about 15 miles beyond Porto Bello. The cement is transported from the States by ship and unloaded into barges for transportation up the old French canal. The cement shed is located alongside this harbor and overhangs the channel so that the material can be unloaded by means of traveling cranes operating on runways extending back into the store house. The rock and sand

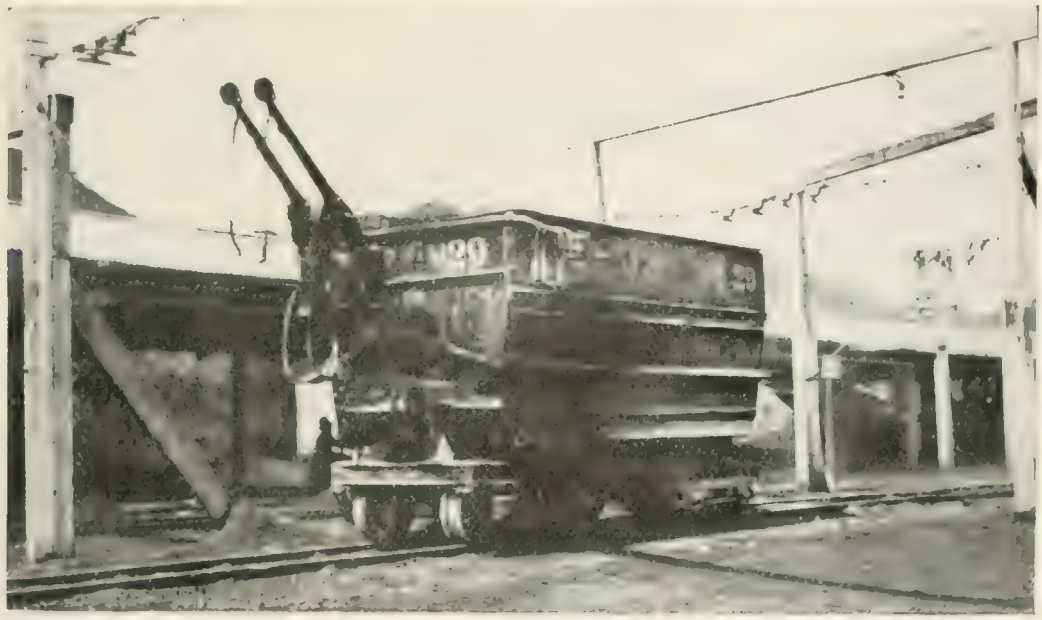


FIG. 2—THREE-PHASE, INDUCTION MOTOR-DRIVEN DUMP CARS

These cars run without an attendant from the stock piles to the mixers, at a rate of about four miles per hour.

are unloaded by means of cableways and stored on stock piles near the cement shed. From this cement shed and stock piles the raw material is transported to the concrete mixing plant by the three-phase automatic railway. The cars used on this railway, shown in Fig. 2, are of the two compartment double truck dump type, each driven by two 7.5 horse-power, three-phase, 25 cycle, totally enclosed squirrel cage motors. Their operation is controlled by attendants located at the various valves and hoppers where they are loaded or unloaded. In starting on a cycle an empty car enters the tunnel under the cement storehouse and is there stopped by an attendant beneath a cement valve where a measured quantity of cement is discharged into the car. It is then started and runs through the tunnel extending beneath the sand and stone stock

piles. It is stopped by an attendant under valves in the bottom of each of these piles and the respective compartments filled with sand and crushed rock. The cars are of such a design that when full they contain the proper proportions for a charge for one of the two-yard mixers. The loaded car travels up an incline to the hopper of the mixing shed where the contents are discharged and the car then started on a similar cycle.

From the mixing plant, the concrete is handled by means of a third rail direct-current industrial railway. The concrete is discharged from the mixer into buckets set on flat cars. These cars are hauled to the desired points along the lock site beneath a second set of cableways, Fig. 3, spanning the lock excavation, that trans-



FIG. 3—PLACING THE CONCRETE AT THE GATUN LOCKS, BY MEANS OF OVERHEAD CABLE WAYS

Four pairs of towers 85 feet high are set on tracks 800 feet apart, and connected by steel wire cableways, two and one-quarter inches in diameter, the pair having a carrying capacity in excess of six tons. The towers can easily be moved along the tracks, so that the carriers can pick up or deposit the big buckets of concrete or other supplies wherever desired, the greatest lift being 170 feet. Twenty trips an hour can be made on each cableway.

port the dump buckets to any point in the lock structure. The hoisting, trolleying and tower moving equipment on these cableways are driven by 500 volt direct-current crane motors. The control is of the unit switch type and the operators are located in the towers at points where they are in a position to see the various signalmen. They cannot, however, see the buckets when depositing concrete in the lock walls. The construction plant was laid out to handle approximately 2000 cu. yds. of concrete per day

but has handled from 3 500 to 4 000 cu. yds. in one day. The floor of the locks varies from 13 to 21 feet in thickness of concrete, and is reinforced with rails from the construction tracks of the French Company. Steel face forms, 78 feet long from top to bottom and 36 feet wide, are used in constructing the side and center walls. They are supported on movable steel towers, mounted on tracks as near the line of the walls as possible. To complete the Gatun Locks will require 2 250 000 barrels of cement. Each lock is 110 feet wide and has a usable length of 1 000 feet.

On the Pacific end of Culebra cut a single flight of locks will be located. The method used in the construction of all of the locks on this side differs radically from those adopted at Gatun, the modifications in general being due to local conditions. As the greater part of the lock construction on this end of the canal is



FIG. 4—BERM CRANES IN OPERATION AT THE UPPER LOCKS AT MIRAFLORES, JULY, 1911

The culvert shown in the wall of the lock, at the right, is 22 feet in diameter, and will be used, together with a similar one in the center and in the other outside wall, for filling and emptying the locks. Laterals, leading alternately from the side and center culverts, are run in the floor at intervals of 32 to 36 feet along the length of the lock, each being fed from five openings in the floor. Valves are so arranged that water may be fed from either of the upper locks to either of the lower, or water from one lock may be used to partly fill the other lock at the same level, thus economizing in the use of water, during the dry season.

at Miraflores, the construction plant was laid out primarily to handle the problems encountered at this point, so that so far as Pedro Miguel is concerned, they have not been able to handle the material as economically as is possible at Miraflores. Even with this handicap they have placed the concrete at a lower cost than at Gatun. The total difference in cost between the concrete at either end of the canal is considerable but a great deal of this is

due to the higher first cost of the raw material on the Atlantic side.

CONSTRUCTION WORK ON THE PACIFIC DIVISION

On the Pacific side the crushed rock is obtained from the quarries and crushing plant on Ancon Hill. The haul from this point to the lock site is almost entirely down hill so that the handling is very economical. The sand comes from the sand pits behind Chame Point about 20 miles west from the entrance of the canal and is brought in barges to the docks at Balboa where it is unloaded by the sand cranes. These cranes are operated electrically by direct-current and discharge the sand very rapidly and cheaply.

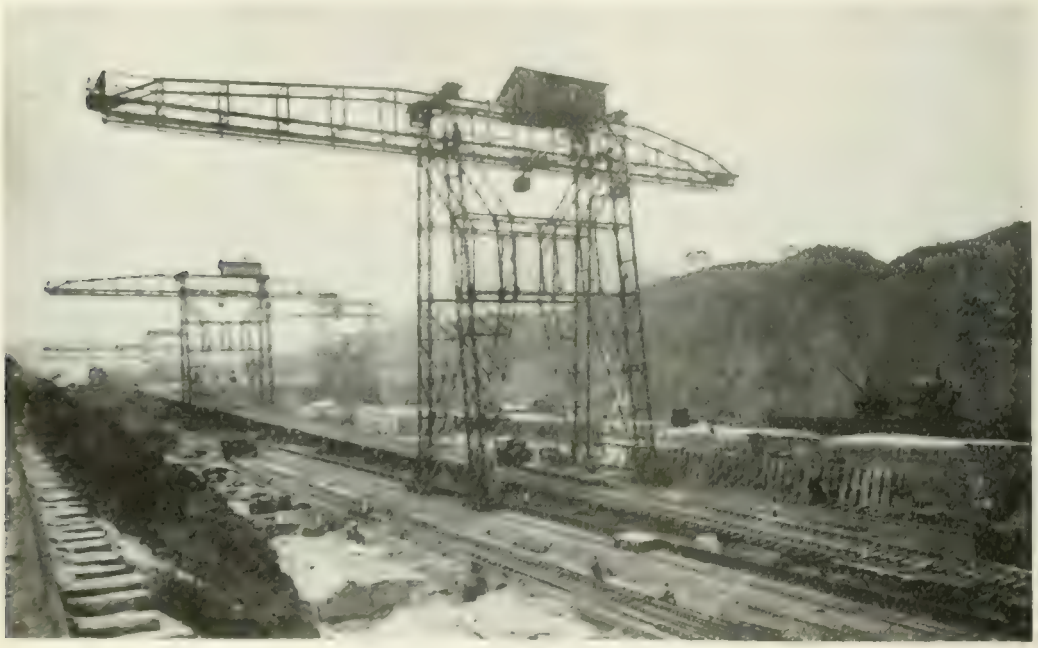


FIG. 5—CHAMBER CRANES IN OPERATION AT PEDRO MIGUEL LOCKS, APRIL 9TH, 1910

Each crane is mounted on four heavy trucks and is movable along the tracks. The operating machinery is located in the house at the top of the tower.

From the docks the sand is handled by rail to the trestles over the stock piles. The cement is transported from the Atlantic side by rail and unloaded at the cement shed or at the mixing plant located in the crane towers. The stock piles and trestles are so arranged that sand is dumped on one side and crushed rock on the other. At Miraflores they are also located adjacent to the lock site the entire length of the locks.

The construction plant for handling the material at the locks on this division consists of cantilever cranes of two types, the so-called berm cranes and chamber cranes. The general type is

essentially the same, the difference being that in the berm crane the fixed cantilevers on one side are replaced by a boom designed for operation in any position from 15 degrees above to 15 degrees below the horizontal The hoists and trolleys are operated by electrically driven hoisting machines installed on top of the crane towers and controlled by operators located in cabs on the trolleys. From this position they are able to see the load at all times and consequently can work to a better advantage than in the case of the operators at Gatun. The two types of cranes are shown in Figs. 4 and 5. The hoisting machines on the chamber cranes and on the booms of the berm cranes are driven by 50 horse-power motors while on the fixed cantilever of the berm cranes 65 horse-



FIG. 6—EXCAVATING BY HYDRAULIC METHOD AT MIRAFLORES

power motors are provided for the hoists on the grab buckets handling the raw material. The control is of the remote electrically operated unit switch type and is arranged for dynamic braking. This feature, in the case of the movable boom, required special arrangement to take care of the different operating conditions. All motors are installed in the operating house and are of the 500 volt, direct-current open type.

At Miraflores, the fixed cantilever arms of the berm cranes extend over the rock and sand stock piles so that the raw material can be handled directly by the grab bucket to the hoppers of the mixing plant in the tower. The concrete is discharged into dump buckets set on a platform on the opposite side of the tower. From here it is handled by the hoist and trolley on the movable boom and

either deposited in the side wall or transferred to the chamber crane by means of which it is placed at any point in the center wall. At Pedro Miguel there is an additional operation, owing to the fact that they are unable to extend the stock piles the entire length of the lock, so that it is necessary to transport the concrete from the mixers to the chamber cranes by means of construction trains hauled by small steam locomotives.

There is a section of canal prism about one and one-half miles below the Miraflores locks that crosses the bed of the Rio Grande several times. The average elevation of rock excavation in this section was minus 30. A careful study of the conditions indicated that a hydraulic excavating plant would be the cheapest and most expeditious method of removing and disposing of the alluvial deposit covering the rock. This involved disintegrating the material and washing it to sumps by means of a water jet under high pressure and lifting and conveying it through pipe lines by means of dredging pumps. The high pressure water supply for the monitors was secured from a central pumping plant built near the section to be excavated on the Rio Grande, west of the canal. In this plant were installed horizontal direct-acting triple expansion pumping engines. The dredging pumps were installed on reinforced concrete barges and in excavating, a section would be isolated by dikes at either end and the water pumped out until there was just sufficient to float the barges at the lowest level, as shown in Fig. 6. The monitors would then be operated near the barges so as to lower them to bed rock and form a pool or sump for the suction pumps. The regular operation of undercutting and sluicing the material to the dredges was then continued until there was insufficient slope for the silt to flow readily. The barge would then be floated to another point. The excavated material was used in part for the hydraulic fill of the Miraflores dam and to reclaim a considerable area of swamp land belonging to the Canal Commission. There is installed on each of these barges an 18 inch centrifugal dredging pump direct connected to a 655 horse-power, three-phase, 25 cycle, 2080 volt squirrel cage induction motor. The power supply to the barges is through lead covered submarine cable from distributing points on shore.

POWER SUPPLY

The power supply for the construction equipment has been furnished by two steam turbine driven plants, one located in a

temporary structure at Gatun and the other in a permanent station at Miraflores. This latter plant will be retained as a reserve for the hydro-electric plant to be installed at Gatun. In each of these stations there are installed three 1500 k. v. a., three-phase, 25 cycle, 2200 volt turbo-alternators. The 500 volt direct-current for cranes, cableways, etc., is obtained from rotary converters installed in the main station.

The permanent equipment to be installed at the different locks will be electrically driven, the power supply being obtained under normal conditions from the hydro-electric station to be installed at the spillway of the Gatun dam. The steam turbine station now installed at Miraflores will be retained as noted above as a reserve and a transmission line to be constructed across the Isthmus will tie in the two stations so that the equipment may secure power from either or both points. The load curve of these stations will approximate that of an industrial power plant. The motors for driving the various machines are of comparatively small size and consequently no extreme or sudden changes of load of any magnitude are expected under normal operating conditions. The average power required by the lock operating machinery for continuous locking will approximate 400 kilowatts, and it is probable that an additional capacity of approximately 2 000 kilowatts will be required to provide for the shops and lights.

THE POWER PHASE OF INDUSTRIAL ENGINEERING

A. F. STROUSE*

"Industrial Engineering is the study of the question of the equivalency between the dollars spent and the things secured."—Going.

EXPRESSED in one sentence, the above statement is probably the broadest and, analytically, the most direct definition that has been applied to the class of service known as "Industrial Engineering." Regardless of the nature of the work, or the angle from which the work is treated, the industrial engineer is invariably striving toward some result which, when attained, will enable his client to get better returns in proportion to expenditures.

The selling price of a manufactured article is fixed by competition, and, since the cost of labor and raw material is virtually beyond the control of the manufacturer, in order that he obtain a legitimate profit on his goods, the cost of manufacture must be decreased, or, what under the conditions amounts to the same thing, the standard of efficiency must be raised. This is the work of the industrial engineer.

Industrial engineering may properly be divided into two main branches: —contructive engineering, for preliminary investigation prior to new industrial developments and for approving the design of new plants as it relates to the efficiency of the process of manufacture and the general welfare of the employees; and reconstructive engineering, for the investigation of established plants with a view to improving conditions by raising the standard of efficiency.

Large industries are almost always the result of gradual growth, hence, in most cases, new machinery and buildings are either additions to existing plants or are provided for the continuation of a business formerly conducted elsewhere. Whenever factories have been put together piecemeal, there are sure to be weaknesses in the general layout, and it is in these instances especially that the industrial engineer can be of service.

Applied to reconstructive work, industrial engineering is again divided into two distinct elements, viz, the human element and the mechanical element. The human element includes the organization and conditions affecting labor. The mechanical element comprises the generation, distribution and utilization of power as applied to manufacturing. This article will deal only with the question of power, first in reference to utilization in manufacturing and sec-

*Of The Industrial Engineering Company, Pittsburgh, Pa.

ond in connection with new developments, the latter being usually central station propositions.

POWER LOSSES BY SHAFTING AND BELTING*

With few exceptions, the greatest leakage of power in a factory occurs where belt drive is used. This is not necessarily due to a faulty or incorrect application, but the very nature of the drive renders the loss unavoidable. Power is lost in transmission through bearing friction on shafting, pulley windage, and belt slippage. Production is lost through belt slippage, breakage of belts, machines operating below rated speed, variations of engine speed, and delays incurred by engine break-downs.

Exhaustive tests, the results of which are on record, show that the waste power consumed by bearings, pulleys, and belts varies from 27 to 75 percent, and in most cases approximates 50 percent of the power generated. It has been found that the friction of a shaft is approximately constant and closely approximates four horse-power per one hundred feet. Also, actual tests show that a simple two-bearing countershaft consumes in friction about 250 watts. It is possible to drive about twenty machines from a 100-foot shaft without crowding. In many shops this number is very much exceeded. Assuming a countershaft for each machine (a condition which usually exists), there is a loss of five kilowatts or 6.7 horse-power due to countershafts. This loss goes on constantly, unless the arrangement is an unusual one, in which the countershaft runs only when the machine is in use.

Power is also lost through slipping of belts. In very few factories are the proper allowances for belt slippage made at the time the plant is laid out. This means that in the majority of plants improper pulley sizes exist, not because the speed ratios have been incorrectly figured, but due to the element of slip having been totally neglected. For example, consider an ideal layout of a 50 horse-power engine belted to a main line shaft 100 feet long, driving twenty machines by countershafts. The belt slippage from the main driving pulley to the driven pulley on the main shaft will be about six percent. On the basis assumed, 4 horse-power is lost in the shaft bearings, 6.7 horse-power in countershafts, and 6 percent of 50 horse-power or 3 horse-power in the main driving belt, a total of 13.7 horse-power or 27.4 percent. This loss is the minimum, and increases with load.

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*All data contained herein is the result of investigations and tests made by The Industrial Engineering Company, Pittsburgh, Pa.

The above 27.4 percent represents the performance with first class equipment and proper pulley sizes, belt widths, etc. It is not difficult to see that this figure would be greatly increased in plants where the system of belting and shafting has been put together piecemeal, with no regard to arc of pulley contact, speed ratios, correct belt widths, proper spacing of bearings, etc. In addition to the above mentioned losses, a considerable loss occurs in belts from the countershafts to the machine pulleys. These losses amount to from 5 to 30 percent depending upon the number of machines running, width of belts and pulley ratios.

In the foregoing it has been shown where loss of power occurs, and it should be borne in mind that a friction loss of from 25 to 30 percent is under ideal conditions, and many times, when indicating engines, it has been found that in order to turn the wheels of the factory, without any machines in operation, requires 50 to 60 percent of the total power developed.

HOW LOSSES IN POWER AFFECT PRODUCTION

The cost of the power wasted in transmission, although large in percent of power used and frequently in dollars, is not usually an important item, because the total cost of power is generally only a small percentage of the total cost of production. But the loss of production caused by the slipping and breaking of belts, machines operating at less than normal speed, variations in the speed of the engine, and through delays incurred by engine break-downs is a serious matter. The ideal condition would be to have each machine throughout the entire factory operate at its maximum speed without any variation or interruption during the working day. This would give a maximum production, and make the quality of the finished product uniform.

Recently the writer had occasion to participate in the investigation of a number of cotton mills in the South. Speed tests were made upon a great many of all types of machines used in this industry. It was found that the greater number of each type were operating not only under speed, but that the speed fluctuated very much. Table I shows the speed fluctuation, the machine manufacturer's rated speed, and at what percent under this speed the machines were operating.

To show how detrimental underspeed operation is to production let us analyze the conditions for a loom. The 32-inch looms in

question were weaving No. 13 warp. It requires 40 picks of No. 13 warp to weave one inch of cloth 32 inches wide. (A "pick" is one travel of the shuttle through the warp.) These looms averaged 157 picks per minute and were designed to run at 170 picks per minute; thus it is seen that 13 picks were lost every minute. In a 3 000 hour year, the normal operating time of cotton mills, this loom would lose 2 340 000 picks per year. Inasmuch as 40

TABLE I—SPEED VARIATION IN COTTON MILLS.

Machine.	Speed Variation	Rated Speed	Percent Under Rated Speed
	Revolutions per minute		
Breakers	1200-1220	1450	16.55
Intermediate Breakers	1120-1220	1450	19.30
Pickers	450- 490	550	14.55
Lappers	1150-1220	1450	18.25
Cards	Normal	....	....
Draw Frames	278- 285	....	....
Slubbers	252- 274	300	12.3
Intermediate Speeders	358- 376	....	....
Finishing Speeders	340- 360	....	....
Spinning Frames	890- 900	....	....
	Picks per Minute		
32 inch Looms	154- 160	170	7.67
36 inch Looms	140- 152	160	8.75

picks are required to make an inch of cloth, this means that, were the loom brought up to normal speed, 2 340 000 ÷ 40 or 58 500 inches, or 1 625 yards more cloth could be produced per loom every year. As this mill has 1 600 looms, this means 2 600 000 yards per year.

It was recommended that motor drive be installed in this mill. Allowing for electrical transmission losses and losses in the motors, it was determined that at least an 8.5 percent increase in production could be effected.

Information was gathered in a number of mills to ascertain the average distribution of operating expense items. This information is used in the following tabulations to show how the net profit is affected by the increased production and is typical of a 60 000 spindle mill.

PRESENT OPERATION

Value of Finished Product		$1 874 500
Fixed Charges	$112 500	
Operating Expenses:		
Salaries and Wages	412 000	
Cotton	900 000	
Miscellaneous Expenses	300 000	
Total Expenses		1 724 500
Net Profit		$ 150 000

OPERATION WITH 8.5 PERCENT INCREASE IN PRODUCTION

Value of Finished Product		$2 035 000
Fixed Charges	$122 500	
Operating Expenses:		
Salaries and Wages	412 000	
Cotton	976 000	
Miscellaneous Expenses	300 000	
Total Expenses		1 810 500
Net Profit		$ 224 500

The above items expressed in percent of the value of finished product would be as follows:—

PRESENT OPERATION

Value of Finished Product		100
Fixed Charges	6	
Operating Expenses:		
Salaries and Wages	22	
Cotton	48	
Miscellaneous Expenses	16	
Total Expenses		92
Net Profit		8 Percent

OPERATION WITH 8.5 PERCENT INCREASE IN PRODUCTION.

Value of Finished Product		100
Fixed Charges	6	
Operating Expenses:		
Salaries and Wages	20.25	
Cotton	48.00	
Miscellaneous Expenses	14.75	
Total Expenses		89
Net Profit		11 Percent

The fixed charges were increased $10 000 per year to cover electrical equipment. This amount is offset somewhat by allowing no increase in miscellaneous expense. This increase in fixed charges, however, does not alter the percentage for this item. Salaries and wages remaining the same under both conditions, the item percentage with increased production is lowered. This also is true for miscellaneous expenses, although this item is cared for, as explained, by the fixed charges. The cost of cotton, in accord with the production increases 8.5 percent, as shown in the second tabulation, the percentage of the value of products remaining the same. The net profit increased from $150 000 to $224 500, or 49.7 percent.

This method of determining the increase in net profit may be used in connection with any industry, the expense items being known. The writer is familiar with an instance of a machine shop having a gross business of $100 000 per year, where the production was increased 20 percent, increasing the net profit 120 percent.

THE COST OF POWER

The industrial engineer finds many plants generating their own power by means of boilers and engines. The question immediately arises:—"Is it possible to secure the required power more cheaply"? In a great many instances large savings can be effected by a scientific analysis of the generating conditions, that is, by studying the combustion chamber, draft, method of firing, steam transmission, etc., and in the engine, by studying the valve action.

Until within a few years ago, small plants had no alternative in the matter of power. They had to have their own generating plant, this being at the time the most economical and satisfactory method. Now central stations are covering almost every territory where industry thrives. Again we come back to the question of equivalency. The problem before the industrial engineer is to determine whether it is cheaper, all things considered, for the manufacturer to retain his present small generating station or buy power from a central station; whether he shall continue driving his machinery by shafting and belting or install a system of motors. To arrive at a decision it is necessary to make a thorough study of power costs.

It is remarkable how few manufacturers attempt to keep a record of their power costs, and it is even more remarkable that where records are kept, they are in most cases found to be incorrect. Many manufacturers who are under the impression that they have accurate figures on the cost of their power, quote costs that are not approached even by large power companies who have the most efficient generating apparatus obtainable and whose sole object is to obtain the greatest economy.

It is a common occurrence to have a manufacturer state that he is generating power as low as one-half or three-quarters of a cent per kilowatt-hour, this including both operating and fixed charges. These figures are very inconsistent when compared with the costs of some of the largest power companies. For instance, there is a large power company in the Pittsburgh district with a modern station having a total capacity exceeding 25 000 kilowatts in generating units, and their cost ranges from 0.7 to 0.8 cent per kilowatt-hour, depending upon the season of the year and the load. This cost is at the switchboard and includes all charges. Their fuel (run-of-mine coal) costs them $0.95 per ton delivered. It is safe to say that there is not a manufacturer in the Pittsburgh district whose power cost even approaches these figures.

To show the cost of power for plants of various sizes, results obtained from the analysis of a power market in one of the cheapest fuel sections of this country, are given in Table II. The manufacturers were buying natural gas at four cents per thousand cubic feet and coal at from $0.70 to $0.90 per ton. A total of 207 plants were investigated, but space does not permit giving the results for all of these, hence the costs for only a typical case for each industry are shown.

TABLE II—COST OF POWER IN INDUSTRIAL PLANTS

Name.	Engine Horse-power Installed.	Load Factor Percent.	Costs per Hp-Hr. Cents.
Mirror Works	60	24	3.406
Belting Co.	75	17	3.644
Brewing Co.	30	11	3.62
Furniture Co.	210	20	2.429
Ice Co.	60	39	2.558
Knitting Co.	250	26	2.383
Engine Works	20	24	3.449
Lumber Co.	150	20	2.39
Lock Co.	250	17	2.07
Milling Co.	50	16	3.46
Machine Co.	50	19	3.33
Brass Works	100	16	3.46
Malleable Iron Works	475	14	2.42
Pattern Works	15	19	2.83
Paper Box Co.	375	20	2.53
Piano Co.	400	12	3.17
Sizing Co.	80	19	3.30
Silver Plate Co.	65	19	3.59
Stamp Co.	75	19	3.35
Builders' Supply Co.	75	16	2.17
Creamery Co.	125	39	2.64
Bolt Works	60	16	2.16
Laundry	50	16	3.76

All users were classified according to the engine horse-power installed. The classification adopted is:—

Class A—Users of 3000 horse-power and over
" B— " " 400 to 3000 horse power
" C— " " 100 " 400 " "
" D— " " 1 " 100 " "

The average costs for all 207 isolated power users in this territory, assigned to their proper class, were found to be as follows:—

Class A—1.45 cents per hp-hr. or 1.94 cents per kw-hr.
" B—1.68 " " " " 2.67 " " " "
" C—2.45 " " " " 3.28 " " " "
" D—3.22 " " " " 4.32 " " " "

In another power market, the cheapest fuel was coal at $2.35 per ton. In this territory it was found that the average costs were

increased only three or four percent over those shown above. The explanation of this condition is, that in the cheap fuel territory there takes place waste and extravagance which would not be countenanced where fuel is more costly.

The figures quoted are representative of the cost of power found in most factories. Every manufacturer should have records showing the quantity of power generated in a given time and the cost per horse-power-hour or kilowatt-hour. Unless such records are kept it is impossible to determine whether or not the existing condition is open to improvement.

The reason why many are in error on the cost of power is the lack of knowledge of the load factor. The load factor is the ratio of the average load to the plant capacity based on 8 760 hours operation per year. There are very few plants that operate every hour in the year, but the load factor should be figured on a full year basis, since the overhead expense is continuous throughout the year. To illustrate how an incorrect load factor affects the cost of power, the following instance of a large Pittsburgh manufacturer is cited. This manufacturer operates a number of plants and was spending $10 000 per year to keep correct power cost records, yet these records were found to be wrong. At one plant the total yearly cost was recorded as $48 000. The plant capacity is 3 000 horse-power and operates 3 000 hours per year. In detail the record was:—

Installed horse-power	3000
Hours operation per year	3000
Load factor	35 percent
Kw-hrs. generated per year	6 700 000
Total cost per year	$48 000
Cost per kw-hr	$0.00715

In this case the error was produced by figuring the plant as operating at full load continuously, the load factor having been deduced from the ratio of 3 000 hours to 8 760 hours. Upon investigation it was found that the average load was only 1 400 horse-power. This reduces the load factor to 16 percent and consequently the number of kw-hours generated per year is decreased proportionally. The correct record is:—

Installed horse-power	3000
Average load, horse-power	1400
Hours operation per year	3000
Load factor	16 percent
Kw-hrs. generated per year	3 140 000
Total cost per year	$48 000
Cost per kw-hr	$0.0153

The owner of this plant had insistently refused to consider any central station proposition, but when an engineering investigation disclosed the true state of affairs, negotiaions for purchased power were opened immediately.

Within the last two or three years the demand for motors has grown at an extremely rapid rate. Manufacturers are coming more and more to realize that electric drive is a practical, money saving method of machine operation. Even in small plants having their own generating apparatus, belting and shafting have been discarded, the engine connected up to a generator and motors installed at the machines. This method is, of course, expensive as the plant has not only the greater part of the former operating expense burden, but has the additional overhead expense of electrical equipment. With purchased power the central station bears this fixed charge, and they can well do it and yet sell power cheaply, because their load factor is high and the equipment the best.

It is a very unusual case in which a saving cannot be affected by substituting motor drive for shaft and belt transmission. The efficiency of electric motors and the necessary wiring is about 80 percent. The theoretically ideal system is one having the tools driven by individual motors. This, however, is not at all times practicable. The arrangement of the motors and their application is one of the problems of the industrial engineer.

The use of motors which are too large for the work is a common fault, and in any case, the best possible results cannot be assured unless the parties handling the applications have made a study of and have had experience in the requirements of special cases.

SOURCE OF POWER FOR NEW PLANTS

Without a thorough analysis of the case at hand, it is impossible to say which source of power for motor drive would best meet the conditions. As far as service is concerned, either an isolated plant or a central station could fill the requirements. This, of course, places no limit upon the size of the isolated plant, which in some cases would have to be so large that, in everything but intent, it would have the aspect of a central station.

The all important item is *cost*. A power plant has two elements making up the cost per kilowatt-hour:—those costs which may be classified under investment, and those costs which are due to operating expense. These are directly dependent upon the character of the work to be done and the load factor. The result

of a careful analysis must form the basis upon which the final decision is made. Of course, there are exceptionally peculiar cases in which certain conditions to be met may make the question of cost a secondary consideration, and naturally, factories situated beyond the limits of central station service are given no choice as to their source of power supply.

The following is a recent instance of a determination made for a new industry:—

A factory was to be built, which would have an average load of 275 horse-power and, to insure absolute continuity of service the owner had planned to install two 300 horse-power steam engines, with the necessary boiler capacity. Power was to be transmitted by shafting and belting. Coal was negotiated for at $2.35 per ton delivered. The plant was to operate ten hours per day. An investigation disclosed the following cost:—

Total initial investment	$50 000
Load factor	15 percent
Investment charges per horse-power hour	$0.01475
Operating charges per horse-power hour	0.01325
Total cost per horse-power hour	$0.02800

It was estimated that the plant would have to generate 788 400 horse-power-hours per year, which at 2.8 cents equals $22 075. A central station in the territory quoted a rate of 2.25 cents per kilowatt-hour, or 1.68 cents per horse-power-hour. The equipment required to utilize purchased power would cost $20 000 as compared with $50 000 for a steam plant.

By using purchased power and motor drive it was possible to eliminate nearly all of the proposed shafting and belting and to increase the efficiency in other ways so that 35 percent of the previously estimated power requirement could be saved. In other words, the energy required would be only 512 460 horse-power-hours or 382 000 kilowatt-hours per year, which at 2.25 cents made an annual power cost of $8 600. The fixed charges on the equipment for purchased power was $3 500 per year. Thus the total annual cost was $12 100. Hence this plant owner saved $30 000 on investment and $9 975 per year on operating cost. In addition there was a gain in production equal to 15 percent over that anticipated.

CHARLES IRA YOUNG

A LETTER OF APPRECIATION.

L. B. STILLWELL

THE passing away, on January 6th, of Mr. Charles Ira Young was a great shock to his friends, many of whom had seen him but a short time before, apparently in his usual radiant spirits. The JOURNAL, which has for years profited by the advice and contributions of Mr. Young, desiring to secure for prompt publication, a personal review of the principal points in his life, requested Mr. L. B. Stillwell, who had known him intimately for many years, to furnish some reminiscences from his personal recollection of Mr. Young. This Mr. Stillwell consented to do.

The example of Mr. Young's noble and courageous life, lived under the most trying and discouraging circumstances, hampered by a physical disability that would have discouraged any but the bravest spirit, was a constant, ever-present inspiration to his intimate friends; and his death was a source of the greatest sorrow to all who knew him. Realizing that no written appreciation can do justice to this brave, inspiring and useful life, yet feeling that all who have had the good fortune to come in contact with Mr. Young will wish to have some permanent remembrance, the following letter is presented. (Ed.)

L. B. Stillwell,
Consulting Electrical Engineer,
100 Broadway, N. Y. City.

MR. A. H. MCINTIRE, Editor,
The Electric Journal,
Pittsburgh, Pa.

DEAR SIR:—Responding to your request for a "personal, intimate review of the life of Mr. C. I. Young for the next issue of the JOURNAL," it is quite impossible for me to prepare without access to data not immediately available anything purporting to be a complete sketch of Mr. Young's remarkably interesting and helpful life. The following is a brief review of his life as I have known it, without attempting to confer with others of his many close friends, who doubtless are familiar with many interesting facts and incidents of which I have not heard or have forgotten. Certainly I cannot hope in a letter to do justice to the memory of a life so exceptionally noble as that of Charlie Young, and it is to be hoped that some of his many friends, better qualified than the writer, will prepare a fitting record of a man who inspired

warmest friendship in all who were privileged to know him—a man whose life was a rebuke to all that is weak or ignoble, and an inspiration to all that is brave and uplifting.

Charles Ira Young—Charlie Young he became instantly to his new friends in Pittsburgh, as apparently he always had been to the entire college community at Princeton—entered the employ of the Westinghouse Electric & Mfg. Company in 1887. He was a son of the distinguished astronomer, Charles A. Young of Princeton, from which institution he had been graduated in 1883. His Princeton friends are better qualified than the writer to describe in detail his undergraduate career, but their testimony is unanimous that in college he was one of the most



CHARLES IRA YOUNG

popular men of his day, and that as a student he made an excellent record. He was a fine musician, and for a number of years officiated at the organ in the college chapel. As an athlete he was particularly distinguished in gymnasium work.

After graduation he entered the employ of the Edison Electric Company in New York, where for several years he acquired valuable practical experience. When he came to Pittsburgh, therefore, in 1887, he came as one of an extremely limited number of college-bred men having practical experience in construction and operation, and was at once sent to Tyrone, Pa., to take charge of the installation of an alternating-current plant, which was among the very early ones supplied by the Westinghouse Company. Upon completion of his work at Tyrone, he re-

turned to Pittsburgh, and some time subsequently was in charge of the installation of alternating-current apparatus at a plant in East Liberty. It is my recollection that in this plant the output was generated at 1 100 volts, and that auto-transformers were employed to produce 2 200 volts for use on one or more of the outgoing circuits. One afternoon Charlie was in charge of a small force of wiremen who were engaged in completing the connections of the auto-transformers to dynamos and switchboard. Five o'clock came and, with characteristic consideration for others, he dismissed the men, telling them that he, personally, would complete the connections. As the men were leaving the building they heard something fall, and returning, found Mr. Young on the floor. It appeared that in making a connection his foot had come in contact with a wire lying on the floor and connected to the opposite terminal of the circuit, and he received practically the full force of 2 200 volts potential between his right hand and foot. He was pulled away from the wires and, soon recovering consciousness, was removed to his quarters at the Amber Club, which then occupied a small residence on North Highland Avenue. At the time, apparently, he was not much the worse for the shock, and after resting a week or so he resumed work, and a short time later was sent to New Orleans to take charge of the operation of a lighting plant installed by the Company in that City. This plant, the largest alternating-current plant in America at that time, comprised five single-phase alternators rated at "1 300 lights each." The building in which they were installed was an old one, and the plant required constant and skillful attention from an engineer both resourceful and courageous. Charlie Young proved to be the right man for the place, and his energetic work was just beginning to show results when paralysis, at first partial and then within a few days total, came upon him. He was removed to the Hotel Dieu, where the good sisters and the medical staff gave him every attention, and here he remained for several months. The consensus of opinion among the doctors who had charge of his case at that time and subsequently, was that the paralysis was a direct although not immediate result of the electric shock which he had experienced at Pittsburgh.

The Company sent one of its engineers to take up Mr. Young's work in New Orleans, and instructed him to see that the best medical skill and attention should be brought to bear upon the case.

Gradual but very slow improvement came after a time, and the Company sent Mr. Calvert Townley, who is still prominently identified with Westinghouse interests, to New Orleans to bring Mr. Young to his home in Princeton. This was accomplished successfully. The train stopped for fifteen minutes at the Pennsylvania passenger station in Pittsburgh, and here a number of Mr. Young's friends met him. Although the only muscles over which he had any control were those of his neck and the fingers of his left hand, he was to all appearances the most cheerful man of the party assembled in the drawing room. He was delighted to see his friends and assured them that, although "laid out

temporarily," he was "still in the ring."

Arriving at his father's home in Princeton, he was put to bed in a comfortable room on the second floor, where he remained for three years; being lifted occasionally from the bed to a reclining chair during the latter part of this period. During this time some of the ablest medical experts of the country gave him their best attention, and gradually he regained partial control of his muscles. The left arm particularly improved, and it continued to improve after this period, until ultimately he was able not only to use it in writing, but also to some extent in playing on the pianoforte. By reading the technical journals he kept in touch with electrical development and also devoted much time to music, in which art he was so skilled that to read a score, even while unable to touch an instrument, gave him much the same sort of pleasure that others derived from reading an interesting book.

Meantime things were happening in the old Westinghouse Electric Company. The years 1889 and '90 were years of great financial difficulty for that corporation. There were changes of management; vice-president Byllesby, who had done everything in his power for Mr. Young, resigned, and soon after some official stopped the payment of his salary, which up to that time had been regularly forwarded to him. The loss of his salary was a severe blow to Mr. Young, as his father was dependent practically upon his modest salary as a professor, and expenses for experts and nurses were high. Not a word of complaint escaped him, however, either to his Pittsburgh friends or to his own family, for his mother told me several years later that never up to that time had she heard Charlie go so far in that direction as to even remark that he was in bad luck.

Following the appointment of the late Lemuel Bannister as first vice-president of the Company, the facts regarding Charlie and his salary were brought to Mr. Bannister's attention, and after some delay the arrears of his salary, amounting then to $1600, were paid up and the regular monthly payment of his salary was resumed.

About three years after the journey from New Orleans to Princeton, Charlie's physical condition was such that he felt himself able to do office work. His mental ability apparently had never been affected in the slightest degree, either by the original shock or by his subsequent physical incapacity, and his many friends soon had the pleasure of welcoming him again in their midst in the offices of the old works on Garrison Alley. By this time the Amber Club had moved from Highland Avenue to a large house with ample grounds, located at the corner of Penn and Murtland Avenues, Homewood, and here for several years Mr. Young lived, attending actively to his work for the Company and surrounded by a group of congenial friends, among whom were Mr. Frank Stuart Smith, Mr. Charles F. Scott, Mr. A. Saunders Morris, Mr. Alexander Wurtz, Mr. Arthur Hartwell, Mr. H. L. Barton, Mr. Philip P. Barton, Mr. Calvert Townley, Mr. Ralph D. Mershon, Mr. D. J. Murray, Mr. Frank Guthrie, Mr. Arthur Davis, the writer, and others.

Subsequently the management of the Westinghouse Company transferred Mr. Young to New York, where he worked in the export department, and still later he became engineer at the Philadelphia office of the Company. In New York and Philadelphia, as at Princeton and Pittsburgh, his remarkable and winning personality made many new friends, while the old ones from Pittsburgh never failed, when opportunity offered, to stop in Philadelphia and look up Charlie Young. This was not done because they felt sorry for him, but because his company gave them exceptional pleasure.

While in Pittsburgh, New York and Philadelphia his mental activity and application were incessant, and he not only kept abreast of the art but, particularly in Philadelphia, found time to do much good original work in connection with various problems which were brought to his attention. He was particularly happy in solving engineering conundrums which were brought to him by commercial representatives of his company, and ultimately established in the Philadelphia office a more or less definitely organized system under which the commercial representatives of the Company were brought frequently and closely in contact with some of its technical experts, to the decided advantage of both. His work in this line was so successful that it attracted attention at the headquarters of the Company, and a few years ago Mr. Young was transferred to Pittsburgh where he was placed in charge of the commercial training department in the sales organization. Under his direction the representatives of the Company in the field have been brought to Pittsburgh systematically in groups and their problems, technical and commercial, have there been discussed with the designing engineers of the Company and with some of its ablest commercial representatives.

In October of last year the writer spent several hours with Mr. Young at Atlantic City, during the convention of the American Electric Railway Association, and was greatly interested in his enthusiastic exposition of the advantages resulting from co-operation of the men in the factory and the men in the field, which he was endeavoring to promote. It was evident that his work was most congenial and, to one who knew him well, no demonstration of the value of his work and of his influence over the young men thus brought together under his supervision, could be necessary.

I have referred to Mr. Young's love of music and his skill in that art. At the old Amber Club in Pittsburgh, prior to the accident in 1888, his musical ability was a source of frequent and intense enjoyment to his friends. He played the piano with rare ability and, with or without the score, would and did give us, upon request, almost anything that any of the boys could think of, from Beethoven, Brahms, Grieg or Wagner to Sir Arthur Sullivan. He also composed, and with considerable success. I remember that among the favorites which were frequently called for by his friends, was one that he called "A Swedish Cradle Song." He played this for us, at least once a week for several months before we discovered that he was its composer. In later years, while he was stationed in New York and Philadelphia, he spent much of his leisure time com-

posing the "Princeton Symphony," which subsequently was performed by the Damrosch Orchestra at Alexander Hall, Princeton, and was enthusiastically received by a large audience.

Since receiving your request to send you a sketch of Charlie Young's life as I have known it, several of his friends have discussed with me his personal characteristics. Not one of these friends have I found who ever heard Charlie utter a word of complaint. I have been close to him under circumstances when any other man of my acquaintance, I believe, would at least have admitted that he was in bad luck, but not so Charlie. His splendid courage, absolute unselfishness, and radiant cheerfulness and good-will toward all about him, made friends wherever he went. The conductors and brakemen who helped him on and off tram-cars and trains in Pittsburgh and Philadelphia and New York; the huge policeman who used to guard the crossing in front of the Equitable Building in Broadway, and stopped the traffic until he got Charlie safely aboard his car; the cab drivers and elevator boys, were all his friends.

A year or two after he was brought north from New Orleans, I called at the Hotel Dieu to convey to the good sisters who had nursed him there, a message which he had asked me to deliver and to thank them for his friends in the North for their care of him while an inmate of their hospital. They spoke of him in terms of high regard, and told me, among other things, that while in the hospital he had, with the help of Mr. Morris as amanuensis, transposed certain hymns for them, and they asked me to tell him that the hymns thus transposed "were now adapted to their voices and were very beautiful." I also learned that when the Fourth of July came, while Charlie was helpless at the Hotel Dieu, he had determined to celebrate the day, and had induced one of the attendants to purchase some firecrackers, which were exploded outside of his window, and had employed an organ grinder to supply music for the occasion. Wherever one crossed Charlie's trail something of this sort was sure to appear, deeds of kindness and evidence of wonderful courage and cheerfulness, even under the most adverse circumstances, marked the course of his career and have made his life an object lesson to all who were so fortunate as to know him. Few men of his generation began their careers in the field of electrical development better prepared, by natural ability or by education, to attain high distinction in the electrical engineering profession. The calamity which came upon him would have left many another man simply a burden to his friends. That Charlie Young not only did not become a burden to others but, notwithstanding the physical handicap imposed upon him, during twenty years of his life following his return from Princeton to Pittsburgh, succeeded in not only holding his own as an engineer but also in the performance of constructive and educational work of a very high order and of far reaching influence, is a fact which should strengthen and stimulate every member of the engineering profession.

Very truly yours,
(Signed) L. B. STILLWELL

ELECTRIC POWER FOR IRRIGATION IN COLORADO

W. H. BULLOCK

THE application of motor drive to pumping for irrigation purposes has not been a serious problem for the engineer. Accurate information applying to a motor driven pump, including a prearranged friction head through the piping outlet can be obtained and used without hesitancy. Troubles which will affect this application and which determine the success or failure of an installation, present themselves, however, in the problem of obtaining water to pump, and the distribution of the water after delivery. Consequently, it is not the purpose of this article to deal other than with the commercial squirrel cage induction motor either belted or direct-connected to a centrifugal pump. As the majority of installations in Colorado cover a head of from 5 to 100 feet, the centrifugal pump is in its proper sphere.

Irrigation pumping has been very successful, but it is not a simple matter to tell where the line can be drawn to determine whether it will be cheaper than distribution by gravity, until the details are given. All Colorado land should be irrigated for cultivation, as the average precipitation in Colorado east of the Rockies is 14 inches, a little greater near the eastern border and less near the mountains, and this 14 inches is not enough for crops raised during off seasons. To support this statement, it is only necessary to state that cultivated land under ditch or having water available by pumping is worth from $100 to $300 per acre. This does not include fruit lands, which may be still more valuable. Arid or dry land used for dry farming is worth $10 to $40 an acre and alkali land is almost worthless. The differences between these figures determine whether or not a farmer wants more water on his land.

Colorado crops comprise chiefly alfalfa, sugar beets, potatoes and grain. There is a great diversity of opinion among farmers as to what amount of water is needed for these crops. General claims are: For alfalfa, three-quarters of an acre-foot to two acre-feet per season; beets, one to one and one-half acre-feet; potatoes, one to one and three-quarters acre-feet, and grain, three-quarters to one acre-foot. The estimate of one farmer does not always check with that of his neighbor, as they do not always know what amount of water they put on their land and, where plenty of water is available, the tendency is to put on too much. Also good judgment is

not always used; irrigating is done during the day under a bright sun or with high winds, in short when the evaporation is a maximum, which results in a waste of water that should be available for more irrigation, or else is a direct loss paid for out of the farmer's own pocket in case of a private power pumping system.

Luckily the kilowatt power input and the amount of water delivered from a motor-driven pump are both easily measured, so that power companies are rapidly contributing data which will at least give accurate information on the water used and the cost thereof, whether applied to waste or usefulness and we are one



TEN HORSE-POWER FIVE-INCH PORTABLE PUMPING PLANT
This outfit pumps from five sources of supply.

step nearer the solution of a problem containing many diverse factors.

Although the government has spent a great deal of money in getting together data and though articles are published from time to time, there is but little useable literature available on the subject. The examples which follow are chosen as typical of the various classes of irrigation, but it will be found that each individual case has conditions surrounding it which must be watched and taken into account.

Four classes of irrigation prevail, which include: First, the gravity system of run off; second, pumping from the run off; third, pumping from the underflow, and fourth, pumping from seepage or drainage.

The first, of course, covers the ditches and reservoirs which the settlers of the country put in when there was plenty of water available and where the only land being taken up was near some supply of water coming in the natural streams. This water is diverted to a storage reservoir and taken from there and from the streams during the irrigation season and put on the land. This available run off, however, did not reach all the land, there usually being some high land having the same quality of soil as the adjoining low land, but no water. Here the pump came into play and the second case resulted. With the growth of the population, the run off was soon exhausted and it became necessary to go below



ARRANGEMENT FOR PUMPING FOR DOMESTIC SERVICE AND FOR IRRIGATING A 175-ACRE GARDEN TRACT FROM A WELL, USING A TEN HORSE POWER MOTOR

the surface and pump from wells,—the third case. The fourth and last case is determined by a question of economy. If there is an old slough on the land where the water comes to the surface and remains for the year around, the water can possibly be pumped back to the high lands cheaper than from a well or ditch with expensive water rights. Along this same line there may be some alkali land that can be drained, the land washed and thereby reclaimed.

GRAVITY SYSTEM

Of the 14 inch precipitation mentioned before on the eastern slope of Colorado, probably about five percent results in run-off or surface overflow, about 60 percent in evaporation and about 35 percent in seepage and underflow. The easier part of this five

percent is what the settlers, who took the initiative in irrigation, obtained. The harder part is what the larger irrigation companies have taken up or are now working on. The investment cost per acre which these projects serve is any where from $15 to $150 and corresponds in a way to the investment in a pumping plant. The crops which the land will produce combined with this cost per acre for water, determine the value of the "Water Right." In Northern Colorado these water rights, sometimes known as ditch stock, average about $60 per acre. The maintenance and operating charges on a gravity system will run from 35 to 80 cents per acre.

As a concrete example of the gravity system, there are in



PUMPING PLANT, IRRIGATING 160 ACRES FROM A WELL

southern Colorado some 80 000 acres of land which it is intended to irrigate by storage of some 100 000 acre-feet of water in a reservoir At present about 5000 acres are being irrigated, the investment to date being about $25 per acre. Maintenance, etc., is from 50 to 60 cente per acre. Twenty percent of the land used less than one acre-foot last season, 60 per cent about one and one-half acre-feet, and the balance one and one-half to two and one-half acre-feet. The irrigation season is about four months in length taken between May and September.

PUMPING FROM THE RUN OFF

An illustration of the second case is a farmer who owned 80 acres of land, 40 of which were under ditch. His time was at first entirely occupied with the 40 supplied with water, but he later determined to put the rest under cultivation. After a careful survey of the land, he found a point where he could reach the highest ele-

vation with the shortest length of pipe line and friction lift and installed a pumping plant. This consisted of two 7.5 kw, 2200-220 volt, 60 cycle transformers and one 15 horse power, three phase, 220 volt 1120 r. p. m. induction motor, direct connected to a centrifugal pump of 900 gallons per minute capacity. A pipe line was run 200 feet to a distribution point where an outlet was made, and from this point the pipe line was continued 235 feet to a second outlet. Twenty acres were covered under a 37 foot lift, 18 acres under an additional 20 foot lift and the balance left, as it would have required about 13 feet additional lift.

As the crops would probably be rotated, the capacity of the installation was estimated to cover any crop. Last season wheat



PUMPING WITH A 30 HORSE POWER MOTOR TO IRRIGATE 160 ACRES OF POTATOES FROM A DITCH

was planted on this land and pumping started about June 1st. During the months of June, July and August, the consumption of current was 2,353 kw-hrs., which cost about $95, or about $2.50 per acre on 38 acres, using about 1.1 acre feet of water for the season. The next year there was more rainfall and his cost per acre was about 78 cents, which illustrates the difficulty of applying detail figures. The cost of the complete installation was about $1200. Before putting in the pumping plant, the land was valued at $21, afterward at $100 per acre.

PUMPING FROM THE UNDERFLOW

With the large areas of land available, Colorado farmers rank high in land-holding acreage per capita and the following example of the third case shows how one man started on a small scale.

He owned 160 acres of arid land, the nearest water being a ditch about five miles away. With no funds available, the cost of bringing this water was prohibitive, so, after trying a number of test holes, a well was located where he was able to obtain about 460 gallons of water per minute. This well was twelve feet in diameter. He struck gravel at six feet, water at 15 feet and reached a permanent depth at 25 feet. The pumping plant included two 2.5 kw, 2200-220 volt, 60 cycle transformers, and one five horse-power, three-phase, 220 volt, 1700 r. p. m. induction motor belted to a centrifugal pump of about 460 gallons per minute capacity. Labor was figured very cheap as he did practically all the work himself, so that the total cost of installation was not over $500, including the well at about $75 and house at $5. He required no pipe line as water was delivered directly to 40 acres of beets from the well. The current during the last season cost about $1.85 per acre-foot, which covered a three months' irrigation period.

PUMPING THE DRAINAGE AND SEEPAGE

A good campaign of education on irrigation problems is being carried on in Colorado. All power companies are endeavoring to extend their lines to the suburban districts and representatives are calling regularly on the farmers, talking electricity for both power and lighting. But against this, the farmer moves slowly and deliberately. An example of this fourth case shows the proverbial exception to the rule.

Eighty acres of potatoes were under ditch when about midsummer in a very dry season, the farmer realized that there was going to be a shortage of water and that possibly his valuable ditch rights would fail him for the first time in ten years. These ditch rights two in number, were valued at $30 000, allowing him 70 inches (748 gallons per minute) of water at certain periods of the year designated by the ditch company. Foreseeing the shortage and knowing of a slough on his neighbor's farm, he purchased the right to pump from this and install a tile drain about 300 feet in length draining into a sump on his own place. Here he put in a ten horsepower motor direct-connected to a centrifugal pump of 800 gallons per minute capacity and ran an eight-inch riveted steel pipe from pump to lateral, 500 feet away.

The cost of installation was about as follows: Drain $185, pump and motor $250, transformers $150, building $25, making a total of about $8 per acre. The potato crop was saved and needless to

say, the pump is in to stay. During the season the power consumption was 2,393 kw-hrs., costing $1.27 per acre-foot. The potato crop was worth $300 an acre.

Another example may be given of a man in Colorado passing from ditch right to seepage. During one season, due to shortage of ditch water it became necessary to install a pump in an endeavor to save 47 acres of potatoes, 45 acres of oats and 65 acres of wheat. Misfortune seemed to prevail, as the water came on the oats too late and the wheat was destroyed by hail but the potatoes were sold two weeks before they were ready to dig for $1800.

A 15 horse power gasoline engine was installed and belted to a



THIRTY HORSE POWER ELECTRO-CONNECTED OUTFIT IRRIGATING A 320 ACRE TRACT

centrifugal pump delivering 1000 gallons per minute. On a 24-hour test run, the engine consumed 50 gallons of gasoline, one-half gallon of lubricating oil and the expense of one attendant. Gasoline cost 18 cents per gallon, lubricating oil about 90 cents per gallon and all had to be hauled about seven miles, taking about 150 gallons of gasoline at a load. The ditch rights became involved in litigation and later a 25 horse-power, 2200 volt motor was installed, the head increased and tests made on it which compared with gasoline as follows:

Gasoline engine .. 900 gals. per min., 23 ft. head, cost $12.50 per day
Motor . . . . 1800 gals. per min., 38 ft. head, cost $17.00 per day

Reduced to common terms, the cost per year to pump a gallon-foot per minute was at the rate of; with gasoline 22 cents; with motor drive 9.06 cents.

The total cost of motor installation was $671. In 1910 the power consumption was 9250 kw-hrs., which figured about $2.64 per acre foot. In 1911, the consumption was only 2770 kw-hrs., costing about $83.

All of the cases given cover irrigation under low heads. Northern Colorado is served exclusively by the Northern Colorado Power Company, whose rate of service, applying to about 3000 horse-power installed in small units, averages three cents per kw-hr. Heads vary from five to 63 feet and an average of 80 acres is supplied from each well, where wells are used. The average cost of installation of a motor-driven pump is $7.50 per acre and the average cost of operation is $2.00 per acre-foot.

On the western slope where fruit lands prevail, higher heads can be pumped against, in one case there being an installation using two lifts, one of 130 feet, and again of 125 feet. The initial cost is figured at a little over $150 per acre and operation and maintenance at $1.60 per acre. Very few projects are attempted where the cost exceeds this amount, as the crops produced will not sustain a higher investment and also, of two similar projects in different localities, one may be successful and the other unsuccessful.

Aside from the above installation on the western slope, Colorado has not been favored with a central power plant for delivery of energy to pumps only. Two very well known installations are near the state, *i. e.*, at Portalles, New Mexico, and at Garden City, Kansas.

At present there is probably no greater activity any where along this line than in the State of Idaho, where the Crane Falls Power and Irrigation Company are involved in a project to reclaim some 30 000 acres of land requiring some 7 000 horse-power in motor driven pumps. The total head will vary from 50 to 175 feet and the investment will amount to some $1 500 000. The United States Reclamation service at Minidoka also have their own generating plant. From central station power in Idaho two recent installations will prove interesting as to costs as soon as available. They are the Indian Cove Reclamation Company, who require two 125 horse-power, 2200 volt motors to pump 3200 gallons per minute each, against a total head of 104 feet and two 75 horse-power, 2200 volt motors to pump 3200 gallons per minute each, against 58 feet head; and the Payette-Oregon Slope Irrigation Company, requiring three 175 horse-power, three 150 horse-power and two 30 horse-power motors.

In presenting the above data, no attempt has been made to advocate or defend the motor as against steam, fuel oil or gasoline for pump drive. A brief statement as applying to irrigation in Colorado will suffice for comparison. Steam is used in outlying areas not touched by transmission lines, but its cost is high. Fuel oil is very often mentioned, but few plants installed, due to high initial costs. Gasoline is really the motor's best competitor, but is being fast laid aside, due to the fact that the farmer is not a mechanic by trade and he does not wish to become an expert in this line just to keep a gasoline driven pump operating. The electric motor has been given a cordial welcome due to its cleanliness, ease of operation, reliability, with no attention required for long periods and reasonable initial and operating costs.

For the benefit of those interested, a conversion table follows, covering values of units commonly used in practice.

TABLE D—HYDRAULIC INFORMATION.

One cu. ft. of distilled water (U. S. Standard), barometer 30", 39.83° Fahr.=62.379 pounds.=7.48 gallons.

One gallon (U. S. Standard)=231 cubic inches=0.13368 cu. ft.=8.3389 pounds water.

One second foot=448.8 gallons per minute,=646317 gallons per 24 hours,=38.4 Colorado inches,=50 California, Utah or Nevada inches=1.98 acre feet in 24 hours=724.5 acre feet in one year.

One Miner's inch (Colo.)=0.025 second feet=11.2 gallons per minute.

25 Miner's inches (Colo.)=1 acre 1 inch deep in 1 hour 37 minutes.

One acre-foot=43560 cubic feet=325851 gallons.

One million gallons=3.069 acre-feet.

One million gallons per day=1.55 second-feet.

One foot head or fall equals a pressure of 0.434 lbs. per square inch.

One pound pressure per square inch equals a head of 2.3 feet.

The pressure of the atmosphere equals 14.7 pounds per square inch.

One pound of water occupies a volume of 27¾ cubic inches.

The spouting velocity of water in feet per second equals eight times the square root of the head in feet.

To find the theoretical horse-power necessary to elevate water to a given height, multiply the gallons per minute by the total head in feet, and divide by 3300. This value should be increased by 50 to 100 per cent to allow for the efficiency of the pump.

To find the velocity in feet per second necessary to carry a given quantity of water in a pipe of given diameter, divide the quantity in cubic feet per second by the area of the pipe in square feet, the quotient will give the velocity.

Tables of friction in pipes of various sizes can be found in the catalogues of pump manufacturers.

ELECTRICALLY EQUIPPED ICE CREAM PLANTS

C. H. McCULLOUGH

THE recognition which is being accorded to ice cream as an important food stuff has transferred it from the category of a mere summer delicacy to its rightful place among staple articles of food for which there is a substantial demand throughout the year. Large quantities are produced daily and in amounts depending less upon the season and outside temperature than might be supposed. Well equipped factories have been built to supply this demand, and these newer plants embody the advanced features of economy and efficiency seen in the most thoroughly standardized manufacturing operations.

The successful manufacture of ice cream requires primarily that all the processes shall be sanitary in the extreme. In practically all up-to-date plants, the milk and cream is pasteurized before it is used. The mixers and the freezers are so designed that they can be cleaned frequently and easily. The piping which carries the mixture, before and after freezing, is made of german silver, or of nickel plated or tinned copper, to insure absolute purity, and is frequently put up in short lengths with readily detachable joints, so that it can be taken down daily and cleaned. The measuring and mixing of the ingredients is performed mechanically, and the cream is conveyed from the mixers through nickeled pipes to the freezers. There is thus no contact with the hands during the entire process.

The actual cooling of the materials is usually accomplished mechanically, rather than by the use of ice, as the latter is expensive, and makes clean and sanitary conditions difficult. The cooling is produced primarily by the expansion of liquid ammonia at a pressure of from 135 to 150 pounds per square inch. As the temperature in the ammonia coils is rather difficult to regulate and as these coils do not lend themselves readily to direct application to the apparatus, it is customary to employ a secondary cooling system. The usual arrangement for the hardening room is to have the ammonia coils in a room or chamber above, and cause the air to circulate around them and then through the room. As the warm air rises and comes into contact with the coils, the air in the whole room soon reaches a temperature below zero. Where a more rapid circulation of the air is desired, a small blower is installed.

The cooling for the pasteurizer, freezers, etc., is usually done by means of circulating brine. The ammonia coils are immersed in strong brine in a large tank, and the ammonia is allowed to expand to a low pressure, reducing the brine to a temperature of 10 to 25 degrees F. This brine is then pumped by means of a small centrifugal pump to any desired location. The advantage of using the brine lies in the fact that it has great storage capacity, and hence will stay cold for many hours after the compressor has been stopped. Thus the compressor may be operated only in proportion to the output of the plant, a condition which tends toward economy of power. The temperature of the brine can also be regulated more closely than can the expanding ammonia gas.

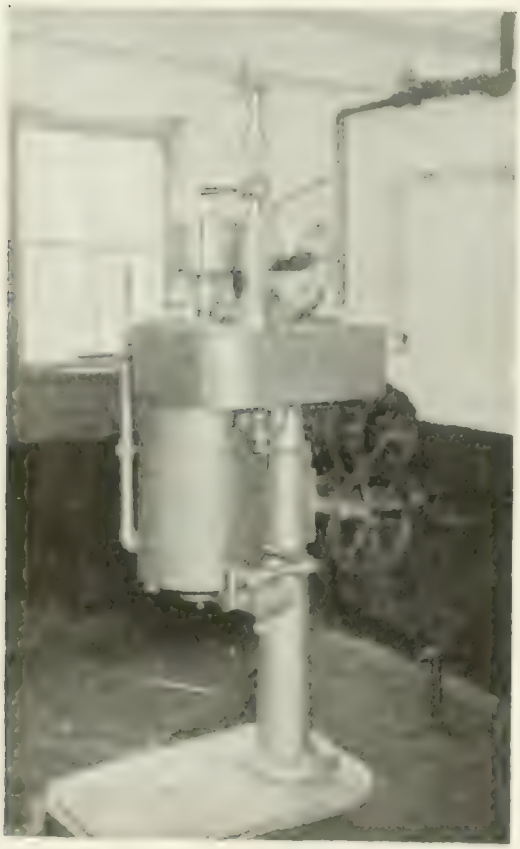


FIG. 1. 40 GALLON FREIGHT ICE CREAM FREEZER DRIVEN BY SQUIRREL-CAGE MOTOR

A typical example of an up-to-date ice cream factory is that of I. N. Hagan's Sons at Uniontown, Pa., which is equipped throughout with modern apparatus. The plant consists of a three story brick building 40 by 70 feet, and from fifteen to twenty men are required to operate the plant at full capacity. The interior walls and ceilings are finished with white Keene cement, with the exception of a gray border extending four feet from the floor, and the floors are concrete, so that the rooms are easily cleaned and kept in sanitary condition.

The normal capacity of the plant is 1000 gallons of ice cream per day, although during the summer season as much as 1 500 gallons per day have been manufactured. Individual electric motor drive is used throughout, which gives the most economical operating conditions for this class of service and also eliminates the use of numerous shafts, bearings and belts, which would tend to

introduce dirt and grease into the cream, power being secured from the lines of the West Penn Electric Company.

In a plant of this type a large amount of refrigeration is required to maintain the cold storage and hardening rooms at the proper temperature as well as for freezing the cream. When ice is used, difficulty is often encountered in the rush season in obtaining a sufficient supply and at the same time the system is very cumbersome and inflexible as compared with electric refrigeration. In the present plant ice is used only for packing the cans for shipment, the remainder of the refrigeration being supplied by a motor-

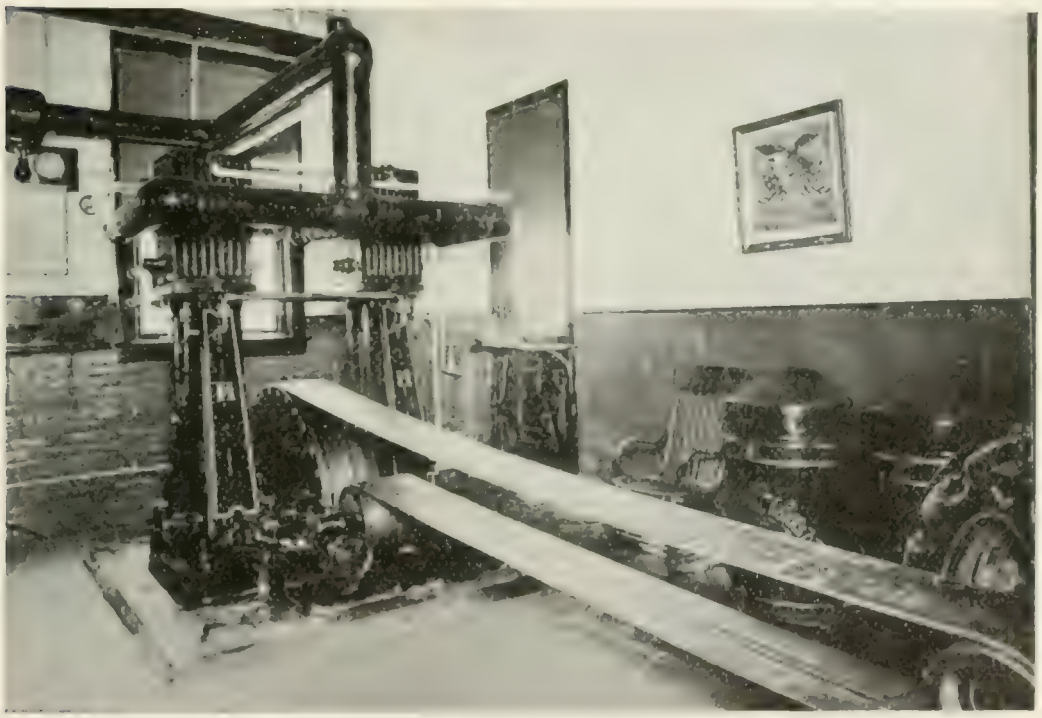


FIG. 2—FIFTEEN TON AMMONIA COMPRESSOR, DRIVEN BY A 30 HORSE-POWER INDUCTION MOTOR

driven compressor. This maintains the desired temperature in the hardening and cold storage rooms besides supplying brine to the freezers and pasteurizer. The compressor, Fig. 2, is of fifteen tons capacity. It is driven by a 30 horse-power, 580 r.p.m., wound secondary induction motor and an idler pulley is used on the compressor to give sufficient belt surface on the motor pulley, and also to avoid cutting into the floor for the belt.

The compression of the ammonia gas heats it to a high temperature, and before it can be used for cooling purposes its temperature must be reduced. This is accomplished by passing the gas, at a pressure of 150 lbs., through a system of condensing coils, consist-

ing of one pipe inside another, the inner one containing water from the city mains, and the outer one the gas, the outside of the pipe being open to the atmosphere. Here the temperature is reduced until the gas, at the pressure used, becomes a liquid. The same water also passes through the jackets on the compressor and cooling coils of the pasteurizer, and then is stored in a large tank on the top floor, from which the warm water supply for washing cans, etc. and for feeding the steam boiler, is drawn. This boiler is heated by gas, and supplies steam at 80 pounds pressure for use in the pasteurizer, for washing and sterilizing the cans, freezers, pasteur-

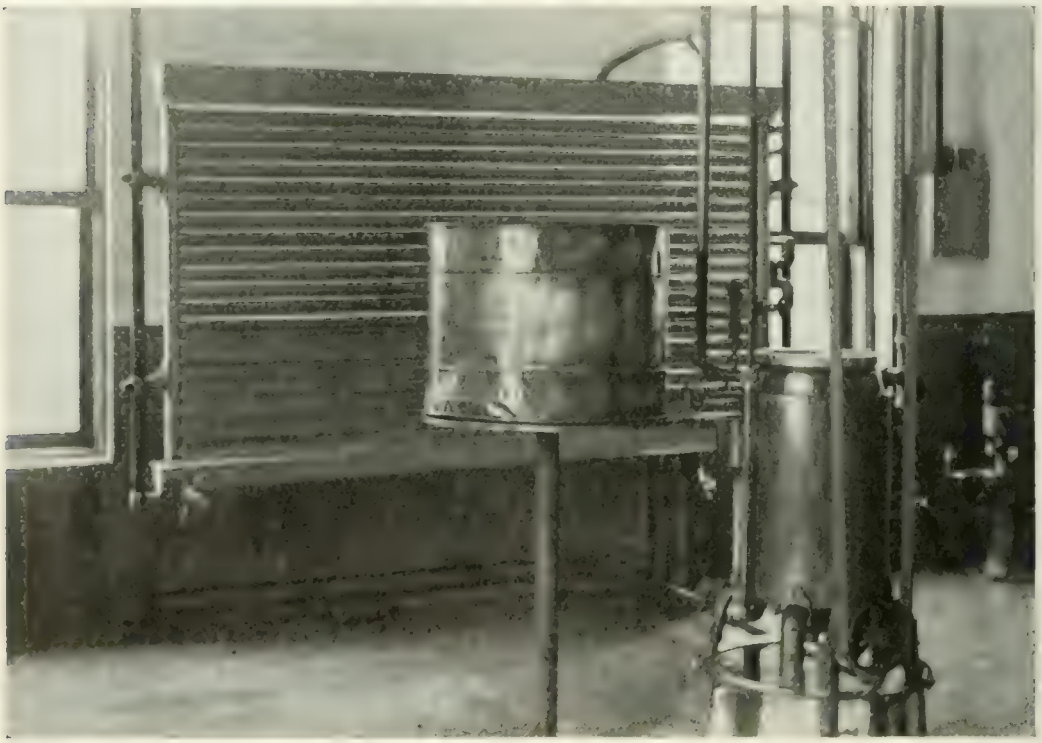


FIG. 3—TWO HUNDRED GALLON PER HOUR PASTEURIZER AND COOLER, DRIVEN BY A FIVE HORSE-POWER MOTOR

izer, etc., and for heating the offices in winter.

As soon as the cream and milk arrive it is tested for butter fats and other ingredients to be sure it is of a certain required quality. It is then rendered free from contagion of any kind in a pasteurizer. This machine, illustrated in Fig. 3, is of 200 gallons per hour capacity, and is driven by a five horse-power, 1700 r. p. m., squirrel cage motor, mounted on the ceiling. The milk is kept constantly agitated by a set of paddles, while it is heated by steam coils to a temperature of 158 degrees F. which is maintained for 20 minutes. It is then pumped into a trough at the top of the cooling coils at the rear of the pasteurizer, Fig. 3, and is allowed to trickle in a

thin stream down over these coils, into the trough below. The upper ten coils contain cold water, and the lower ten brine, thus reducing the temperature of the cream to about 50 degrees F. It is then placed in one of two cold storage rooms on this floor until required for the manufacture of ice cream. These rooms have a capacity of 3000 gallons and are used only for the storage of dairy products. They are kept at a temperature slightly above freezing by the brine which is circulated through the cooling coils, as well as through the pasteurizer and freezers, by a two inch Worthington volute pump, coupled to a five horse-power, 1700 r. p. m., squirrel cage motor, shown in Fig. 4.

The ingredients of the ice cream are mixed in a large copper tank, with slowly revolving agitators inside. The mixer, Fig. 5, has a capacity of 300 gallons, and is driven by a two horse-power, 1700 r.p.m., induction motor. Sugar is stored in a fifteen-barrel bin on the floor above, and is drawn into the mixer through a chute. The mixer is located on the second floor, just above the freezers, and the "batch," as it is called, is drawn into the measuring chambers on the freezers by gravity.

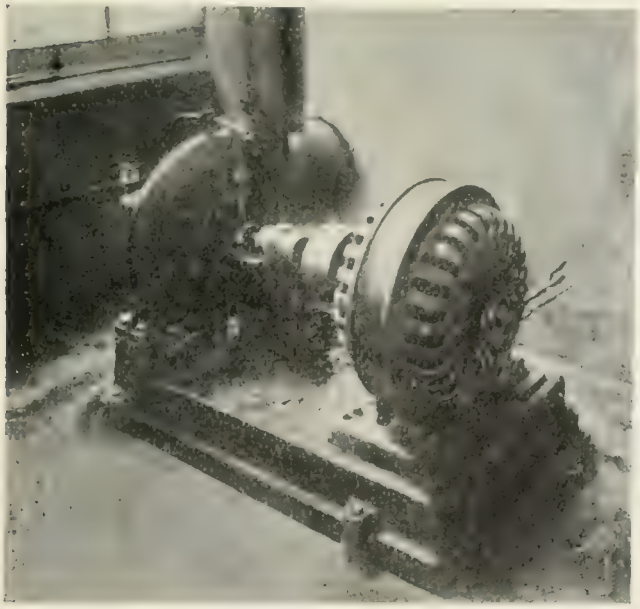


FIG. 4—TWO INCH VOLUTE BRINE PUMP, DRIVEN BY A FIVE HORSE-POWER INDUCTION MOTOR

As shown in Fig. 6 the measuring device consists of a copper tank with a glass gauge on the front, so that just the amount of the mixture may be run in which will fill the freezers when the cream is frozen. The cooling is done by brine circulating in coils around the freezer at a temperature of about 12 degrees F. The freezers are individually driven by two horse-power motors, and have a capacity of ten gallons of ice cream which can be frozen in ten to fifteen minutes, giving a twenty-four hour capacity for the three, of 1 500 gallons.

The cream is stirred rapidly in the freezer until it is all crystallized, securing the fine smooth consistency which is characteristic

of the machine made product. It is then transferred in the form of a soft slush into standard two, three and five gallon cans and placed in the hardening rooms to harden, and for storage. There are three of these hardening rooms on the first floor, each 6 by 11 feet and 9.5 feet high, opening into a vestibule 5 by 18 feet. They are cooled by the indirect system, the air being circulated by a 30 inch fan driven by a three horse-power, 1 700 r.p.m., induction motor. The ammonia coils, 3 800 feet in length, are in a compartment above the rooms and the air passes over these coils and into the rooms at one end and out at the other end of the ceiling. This system is considered superior to cooling by brine coils, in that the air can be made much colder than brine, and can be brought into more intimate contact with the cans. Practically any temperature may be maintained, although the average temperature is from 10 to 15 degrees F. The walls are insulated with four inch ground and six inch sheet cork. Each room is equipped with electric lights, specially designed thermometers and a push button by which a bell can be rung in the office in case anyone becomes accidentally imprisoned.



FIG. 5—THREE HUNDRED GALLON ICE CREAM MIXER, DRIVEN BY A TWO HORSE-POWER MOTOR

The vestibule of the hardening room is so designed that one door opens into the freezer room and another into the shipping room. As previously stated ice is used only for packing the cans for shipment, and the ice storage (8 or 10 tons) is so located that it is easily filled from the outside while from the inside the cakes can be drawn directly into an ice crusher. This crusher, Fig. 7, is driven by a three horse-power 1 700 r.p.m. induction motor, and will crush a 200 pound cake in about 30 seconds. The salt which is used with the ice for packing is obtained from a large storage bin on the third floor by means of a chute.

Besides the above equipment there is a three horse-power, 1120 r. p. m. induction motor belted to the driving mechanism of a 1500

pound freight elevator used to carry supplies to the second and third floors. The wiring is all installed in conduit.

Although the electrical equipment in a plant of this nature effects a saving in operating expenses, the greatest advantages are in the flexibility, cleanliness and consequent saving of material. To meet demands for increased production it is simply a question of operating the refrigerating machine a little longer each day and maintaining the brine and hardening rooms at a lower temperature. As the weather becomes colder, and the demand for cream slightly less, the number of hours during which the compressor and other motors are operated is greatly reduced, with a corresponding saving in power consumption.

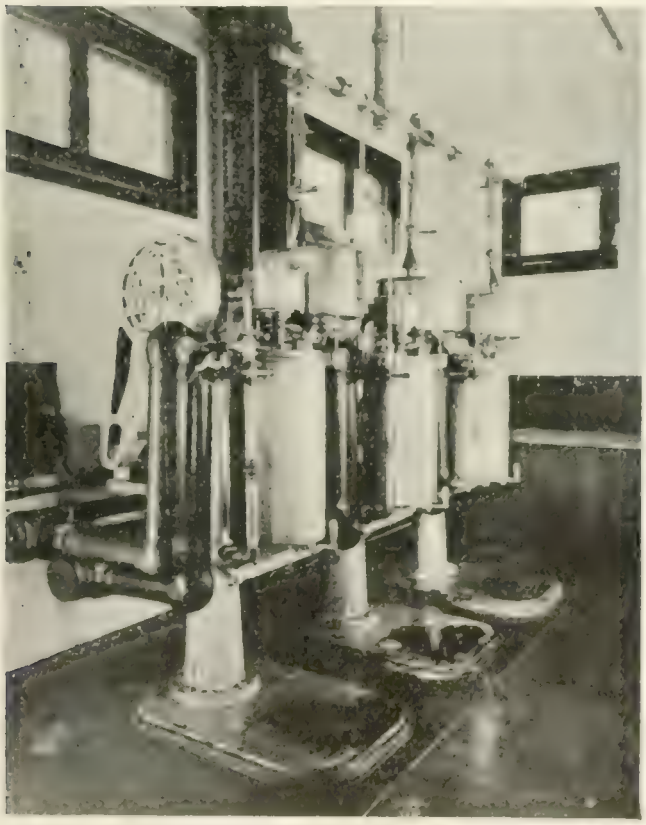


FIG. 6—TEN GALLON ICE CREAM FREEZERS, INDIVIDUALLY DRIVEN BY TWO HORSE-POWER MOTORS

One of the most important features in connection with the manufacture of ice cream in large quantities is the cleaning of the storage tanks and cans, and the machinery. Every part of the machinery, piping, etc., that comes into contact with the various ingredients is cleaned with hot water and soap at least daily and is then sterilized with live steam. The cans are cleaned after each using by means of a motor driven cleaner, consisting essentially of a large brush revolving in hot water. The cans are slipped over this brush for a few seconds and are then sterilized with live steam.

There are nine motors in the Hagan plant, with an aggregate capacity of 57 horse-power. The power consumption from April 1 to December 1, 1911, averaged 0.58 kw-hr. per gallon of ice cream frozen, and the load factor on a 24 hour basis over the same period of time was 11.7 percent.

With regard to power consumption, ice cream factories are divided into two classes. The first and largest class includes those plants which are operated in connection with small confectioners' establishments, hospitals, hotels, etc., in which the refrigeration is furnished by ice and no power refrigeration is necessary. Where a freezer and ice crusher alone are used, the power consumption for plants under 30 gallons per day will vary from 0.05 to 0.1 kw-hr. per gallon of ice cream, depending on the efficiency of the power application. On larger installations, the consumption will be somewhat smaller; one plant with a capacity of 1 000 gallons per day operates with a current consumption of 0.04 kw-hr. per gallon.



FIG. 7—ICE CRUSHER DRIVEN BY A THREE HORSE-POWER MOTOR

Where motors are depended upon to furnish power for artificial refrigeration, the consumption is, of course, higher. The plant of I. N. Hagan's Sons may be taken as typical of such installations, and the power consumption is representative, the current in other plants on which information is available varying from 0.5 to 0.78 kw-hrs. per gallon of ice cream, while the 24 hour load factors vary from 10 to 15 percent and in a few instances as high as 20 percent, depending, of course, on the amount of business done.

LIFT BRIDGES ON THE NEW HAVEN RAILROAD

R. W. EATON

THE Harlem River Branch of the New York, New Haven and Hartford Railroad passes over two draw-bridges, each of which is made up of three leaves; each leaf carries two of the six tracks of the branch over which, at present, pass approximately 200 trains daily. The Bronx River bridge is near the Westchester Avenue station, and is designated as bridge number 3.40; the Hutchinson River bridge is between the Baychester and Bartow stations, and is numbered 7.73. Both are of the Scherzer rolling lift type, and were completed in the summer of 1908.

As the channels spanned by these bridges are only about 100 feet wide, the rolling lift construction was adopted, as this type requires no center pier, and no obstruction or widening of the channel. The three leaves of the Bronx River bridge are shown in Fig. 1 in the open position, and a detail of the ways upon which one leaf rolls is shown in Fig. 2. The number of daily openings is variable, averaging as low as four in the case of the Bronx River bridge during some winter months, while it may average 12 daily in some other months. The average number of openings of the Hutchinson River bridge is considerably smaller.

Each leaf of the bridge is operated by motors mounted on the moving leaf, geared to a pinion which projects from the side and meshes with a stationary rack. This rack may be seen at the right of the bridge in Fig. 1, and again in Figs. 2 and 4. In laying out the electrical equipment, a number of requirements had to be met. The motors, brakes, and other apparatus on the bridge itself must be weatherproof, and the lubrication, etc., must be designed for successful operation through an angle of 90 degrees, as the bridge rotates through this angle. The power, control, brakes and signal circuits must be carried from the operating tower to the bridge proper, no moving part of which moves less than about 15 feet; interlocks must be arranged so that the controllers cannot be operated until signals are properly set against trains, and the bridge unlocked; signals (lamps and bells) must be installed so as to keep the operator advised of the exact position of each leaf, and the power automatically cut off and brakes applied when any leaf approaches the end of its travel.

The power supply in each case is a 550 volt grounded direct-current circuit. On each leaf are mounted two 25 horse-power, 600 r. p. m. crane motors, each having a shunt connected, controller-operated brake on the shaft. There is also on each leaf a powerful emergency band brake, operated by a switch in the operating tower. The conductors to the moving part of the bridge are carried in metal conduit to a point which may be seen near the lower left hand side of Fig. 2, where they pass to the upper side of the roll way, and (when the bridge is open, as shown) lie along a

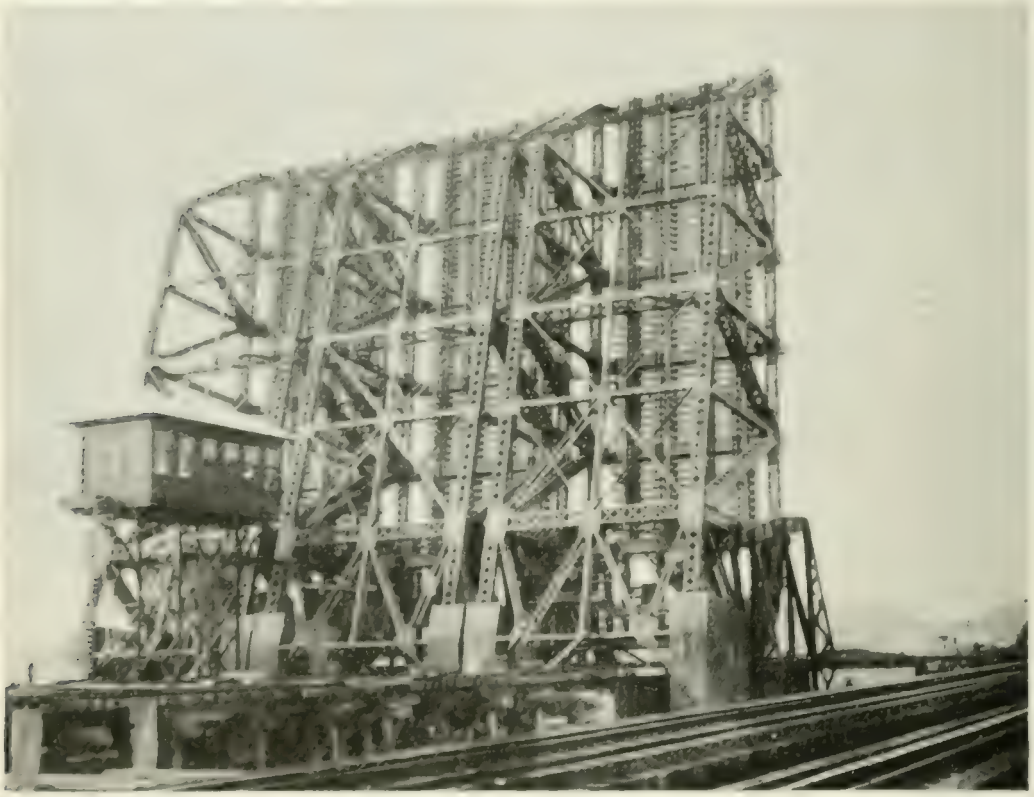


FIG. 1—ROLLING LIFT BRIDGES OF THE NEW YORK, NEW HAVEN & HARTFORD RAILROAD OVER THE BRONX RIVER

The central tower affords the operator a clear view of the river and of the railroad.

trough to the point where they are carried up into the bridge itself, entering at the point marked *A* in Fig. 4. As the bridge swings down, the point where the cables enter the leaf moves upward, and the slack cable rises out of the trench. In Fig. 4, the dotted line B-A_1 shows the position of the cable when the bridge is open. The motors and a portion of the gearings are shown in Fig. 3.

The movements of the bridge are controlled from a tower in which is installed a four-panel switchboard, controllers and signal apparatus. Panel 1 controls the incoming power supply, and panels

2, 3 and 1 the separate leaves of the bridge. The signal lamps and bells are mounted on the rear wall, and some distance above the top of the switchboard. The three grindstone type controllers are directly in front of windows from which the bridge itself may be observed. On each of panels 2, 3 and 1, are two double-pole switches, which allow the two motors on each leaf to be operated in parallel as one unit from one controller. By opening one switch, either motor may be operated alone. Either motor can operate its leaf in ordinary weather, though of course taking longer than

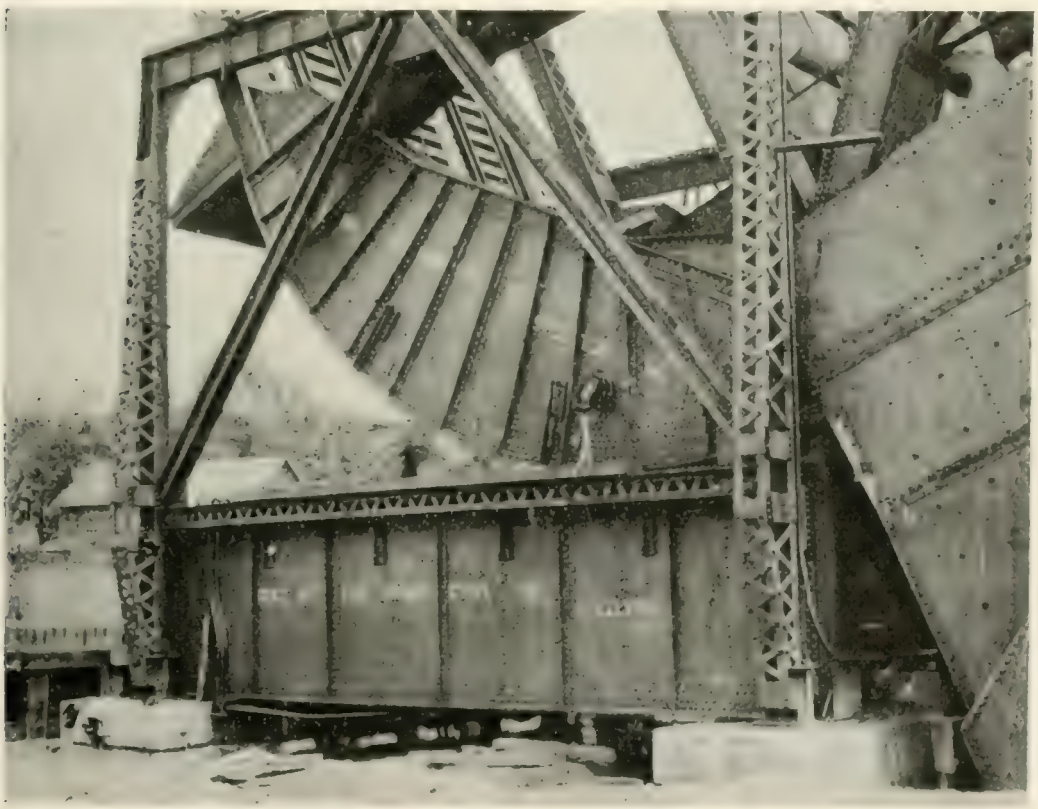


FIG. 2—DETAIL OF LIFT BRIDGE

Showing the ways upon which the leaves roll, and the method of conveying the wiring to the moving element.

when two are used. The first controller position releases the motor brakes, but power is not applied to the motor itself until the controller is advanced to the second notch.

Several feet above and behind each motor panel a small panel is mounted into which are set eight glass lenses, numbered respectively from 5 to 12, with a lamp behind each lens. When the bridge is in the closed position, and the incoming line switch is closed, lamps 5 and 7 are lighted; lamp 6 lights as soon as the mechanical bridge lock is released. In order to open the bridge,

the signals must first be properly set against trains, and de-rails opened; this having been done, the bridge rail-lock mechanisms are released by an interlock and may then be opened; then a mechanical interlock is released, which allows the controllers to be operated and the upward movement of the bridge started. As the bridge rises and reaches the first intermediate point, the lamp behind lens *8* on the indicating board is lighted, and the bell rings; as the leaf rises still higher, it passes the second, third, and fourth intermediate positions, lighting successively lamps *9*, *10* and *11*. At the point

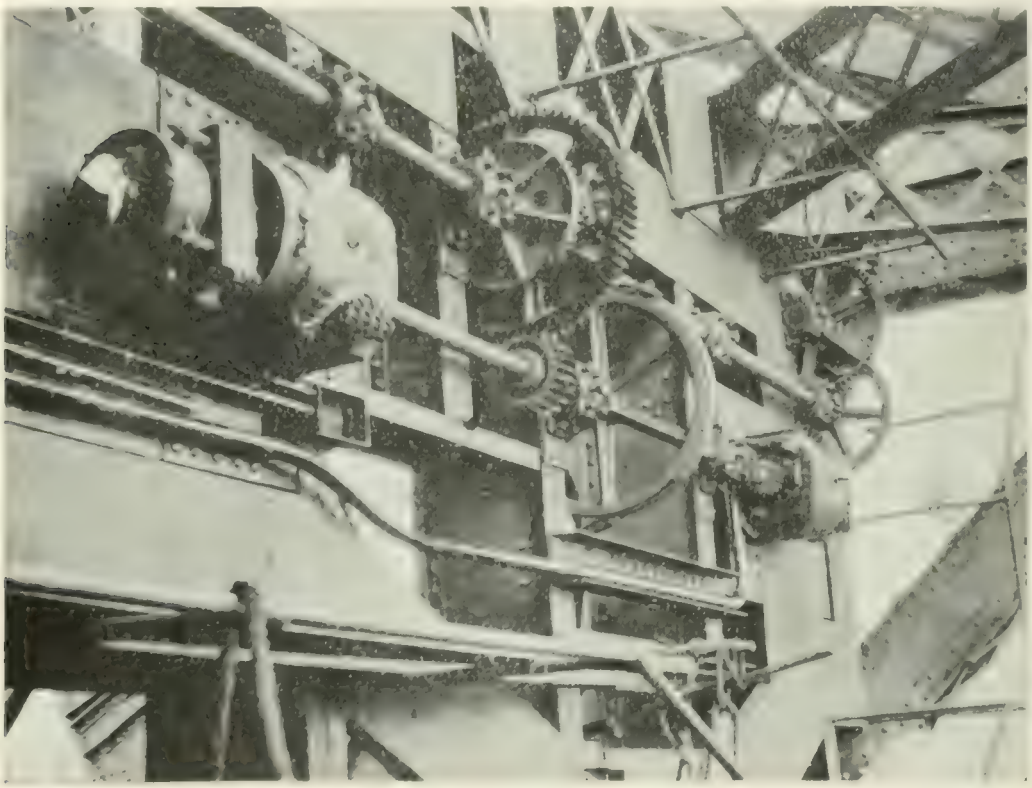


FIG. 3.—[illegible] HORSE-POWER, 600 R.P.M., CRANE TYPE MOTORS ON [illegible] BRIDGE.

where lamp *11* is lighted a bell rings, and it is customary to shut off power, as the leaf has reached a nearly vertical position. If, however, the operator neglects to shut off the power, and the leaf rises still higher, lamp *12* is lighted, and the circuit breaker on the leaf is automatically opened by means of a shunt trip-coil. A lever is carried by the moving part of the bridge, which, when it reaches the open position, closes a circuit to navigating lights on the river, changing them from red, their normal color, to green.

The connections to the various signal lamps and bells are made by means of six control cables per leaf, extending upward, and sup-

ported on composition insulators at points along, and just outside of, the rack along which the driving pinion moves. These contact shoes are so arranged with springs below, that they may be pushed downward a short distance. Each is connected to the positive side of the supply circuit through its corresponding signal lamps. Beyond the outer end of the driving pinion is a metal disc, connected electrically and mechanically to the pinion and, of course, to ground. As the bridge is raised or lowered, and the pinion travels along the rack, this disc passes over and makes contact with the contact shoes, completing the circuit through the various lamps and bells. Each circuit so made is opened again as soon as travel has progressed further to a point where the disc passes off each contact shoe. The length of each shoe is about six inches.

Under normal conditions, the three leaves of bridge 3.40 can be

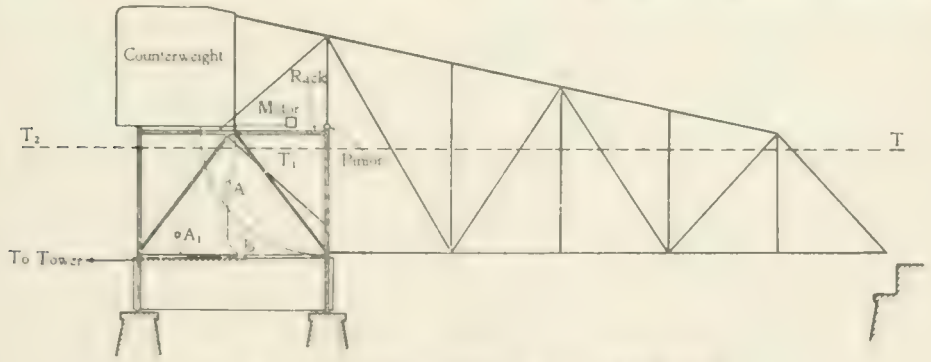


FIG. 4—OUTLINE SKETCH OF LIFT BRIDGE

B-A, position of swinging cable when bridge is closed.
B-A_1, corresponding position when bridge is open.
T, T_1, T_2, approximate position of 11 000 volt trolley when bridge is closed.

raised simultaneously in about one minute, using two motors per leaf, and taking a total running current of about 210 to 260 amperes at 550 volts. The current to start the three leaves is about 40 to 50 amperes greater for a short time. The power requirement varies considerably under different conditions of the bridge, and of sleet, snow, wind, etc., but an average for a month when there was no snow or sleet shows that bridge 3.40 requires about 2.25 kilowatt-hours per operation. The bridge will usually close itself, power being applied only to start it.

As the Harlem River Branch, upon which these bridges are located, is being completely electrified, it became necessary to work out, for the first time in this country, the proposition of carrying the 11 000 volt contact wire of the single-phase system across a lift bridge. As the installation is not completed, only a general idea of

the method by which the problem has been solved by the railroad company's engineers can be given here. In Fig. 4 the dotted line T-T_1-T_2 represents the approximate position of the contact wire; at the moving end of the bridge a supporting structure is attached to it, which supports the wire at approximately the point T, and a similar structure is built on the shore, with an anchor bridge a short distance behind to take up the strain of messengers and contact wires beyond. At T the contact wire from the bridge terminates in an arm which carries a contact making device which, when the bridge closes, makes electrical connection with an arm from the shore end of the trolley and conversely, when the bridge opens, will break this connection, thus isolating the bridge section, there being a section break beyond T_2. Between points located approximately at T_1 and T_2 the contact wire hangs free, being kept under tension when the bridge is closed by a clever tension spring device at T_2. When the bridge is fully open, the section of contact wire T_1-T_2, of course, hangs slack and near the ground, but this makes no difference, as the section is electrically disconnected as soon as the bridge starts to open. Feeder and other wires are carried on a span over the stream, between towers on either side, the minimum height of the span above water-level being 135 feet.

Each leaf is arranged so that it may, in emergency, be manually operated by means of an endless chain over a wheel on the counter-shaft. It has, however, never been necessary to use this arrangement since the bridges were put into regular service several years ago.

METHOD OF MANUFACTURE OF MARBLE PANELS FOR SWITCHBOARDS

H. C. PRATT

MARBLE is used very generally for switchboard purposes, because of its physical and electrical properties. The important part which electricity plays in the quarrying of the raw material and in the subsequent manufacture of the switchboard panels, in the case of some of the larger marble companies, is probably, however, not so generally known. It is not too much to say that, without the use of electrically operated machinery, the present state of development of the marble industry in Vermont, for example, would have been impossible. In the case of the Vermont Marble Company, where the electrical development has been extensively carried out, power is generated at two points on Otter Creek. At Proctor, where the river has a fall of 120 feet, three 750 kilowatt generators are installed. At Huntington Falls, about thirty miles distant, there is a second plant containing two generators of like capacity. An extensive transmission system connecting the two stations supplies power to some half dozen outlying mills and quarries.

At West Rutland, where quarrying methods have reached the fullest development, the deposit extends north and south for a distance of about one-half mile and has an extreme width of 150 feet at the surface. Here the layers are nearly vertical, but, at a depth of about 175 feet, they dip sharply to the east and at the bottom of the quarry lie at an angle of about 30 degrees to the horizontal. Beyond this dip the vein has been compressed and has a thickness of 50 to 75 feet. Large rectangular openings have been made at the surface, and from these tunnels have been driven. One tunnel extends some seven hundred feet north and south along the vein, and in another quarry the layers have been followed nearly eleven hundred feet toward the east. The soundness of the deposit makes timbering of the tunnels unnecessary, but occasional piers of marble are left to support the roof. The deposit comprises a large number of distinct layers; white, blue, green and pink, and various other colors. Each quarry along this vein produces about twenty varieties, to which different trade names have been given.

The use of explosives in the quarrying of marble is not desirable. The blocks are cut from their bed by the use of channelling machines, each of which consist essentially of an electric

motor driving an air compressor. The latter operates a group of drills forming a cutting head. A block, having been cut on four sides, can then be broken from its bed by wedges. Large derricks, equipped with electric hoists, lift the blocks to a car and an electric locomotive carries it out of the tunnel to a point where a derrick on the surface can reach it. The quarries are lighted by arc lamps and, in the tunnels, operations may proceed throughout the year without regard to weather conditions. It will readily be appreciated that electricity has made possible the cutting of marble in places where



FIG. 1—HYDRO-ELECTRIC STATION OF THE VERMONT MARBLE COMPANY AT SUTHERLAND FALLS, PROCTOR, VERMONT

It is interesting to note that the generating station and the walls shown at the right, as well as many of the buildings around the works, and even some of the public sidewalks are made of squared marble blocks. The waste sand from the marble cutting is conveyed over the bridge, shown in the foreground and deposited across the river. This sand is brought to the mills by a reciprocating system, 2.5 miles long, having a capacity of 3.5 tons per hour, and is used hot, now.

the steam machine would be impracticable or expensive in operation.

From the quarry, blocks are transported by railroad to the mills, or else to the storage piles where electrically operated cranes deposit them for future use. Before leaving the vicinity of the

quarry, the blocks are washed off so as to detect possible defects, and are given some distinctive mark.

On arrival at the mill the blocks are unloaded by electric traveling cranes, being piled under the craneway or taken directly into the mill. In the mill the blocks are cut into slabs or panels by means of "gangs" of saws arranged in line on either side of the track and driven from a line shaft above, the latter being operated in sections by direct-connected motors. A track extends through the center of the mill and runs under the craneway outside. An electric locomotive crane operates on this



FIG. 2—MARBLE QUARRY, WEST RUTLAND, VERMONT.

The blocks are lifted out of the quarry by the boom hoists at the right and deposited on cars or in the storage yard. The operators use the stairs shown on the far side of the opening.

track, power being furnished by an overhead trolley. The blocks are loaded on low four-wheeled cars, which in turn are placed on the platform of a second car and hauled into the mill. On arriving opposite the proper gang saws, the smaller car containing the block is hauled from the main car onto a track extending under the gang.

The saw blades are of plain steel, about one-eighth inch thick A constant stream of sand and water flows onto the block from above. The action of the gang is similar to that of an ordinary crosscut saw; the sand taking the place of the teeth. The number and spacing of the saw blades depends on the use to which the mar-

ble is to be put; seven-eighth inch slabs being the thinest commonly sawed. A suitable feed moves the gang downward as the sawing progresses, the advance depending on the number of blades and the hardness of the marble. On ordinary Vermont marble, sawing the blocks into two inch slabs, the progress is at the rate of about one inch per hour.

After the slabs have been sawed they are removed from the gang and taken to the finishing shop. Here they are washed off and, before being coped, i. e., trimmed roughly to size, are examined for unsoundness. At this point, small cracks not noticeable in the rough block may develop, thus rendering the slab useless, except for pieces of smaller size. The slabs are coped by

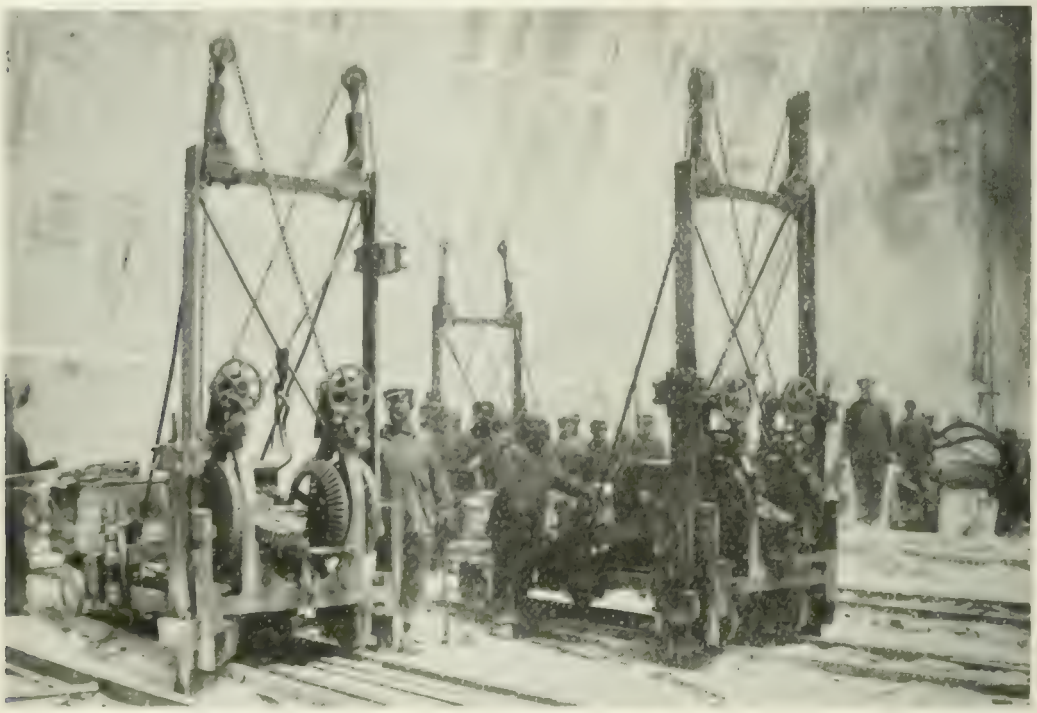


FIG. 1—CHANNELING MACHINES IN OPERATION IN MARBLE QUARRY

Channeling operations are carried on in several levels at one time.

hand or by an air chisel to the approximate sizes required.

They are then brought to their final dimensions by means of a rubbing bed, which consists of a circular iron plate, usually twelve to fourteen feet in diameter and five inches thick, mounted horizontally on a pivot and rotated by a vertical stem or shaft bolted to the center of the plate. The marble is laid on this bed, and is kept from rotating by beams supported just above the surface of the rotating bed at intervals around its circumference. A stream of sand and water, which flows onto the bed near its center, furnishes the cutting material, and is kept uniformly distributed by the centrifugal action. The marble ordinarily rests on the rubbing



FIG. 4—QUARRY VIEW, SHOWING ELECTRIC DRILL IN OPERATION

The blocks are cut on three sides from the top by the channeling machines, and are undercut, as shown, by the drills, working on a lower level.

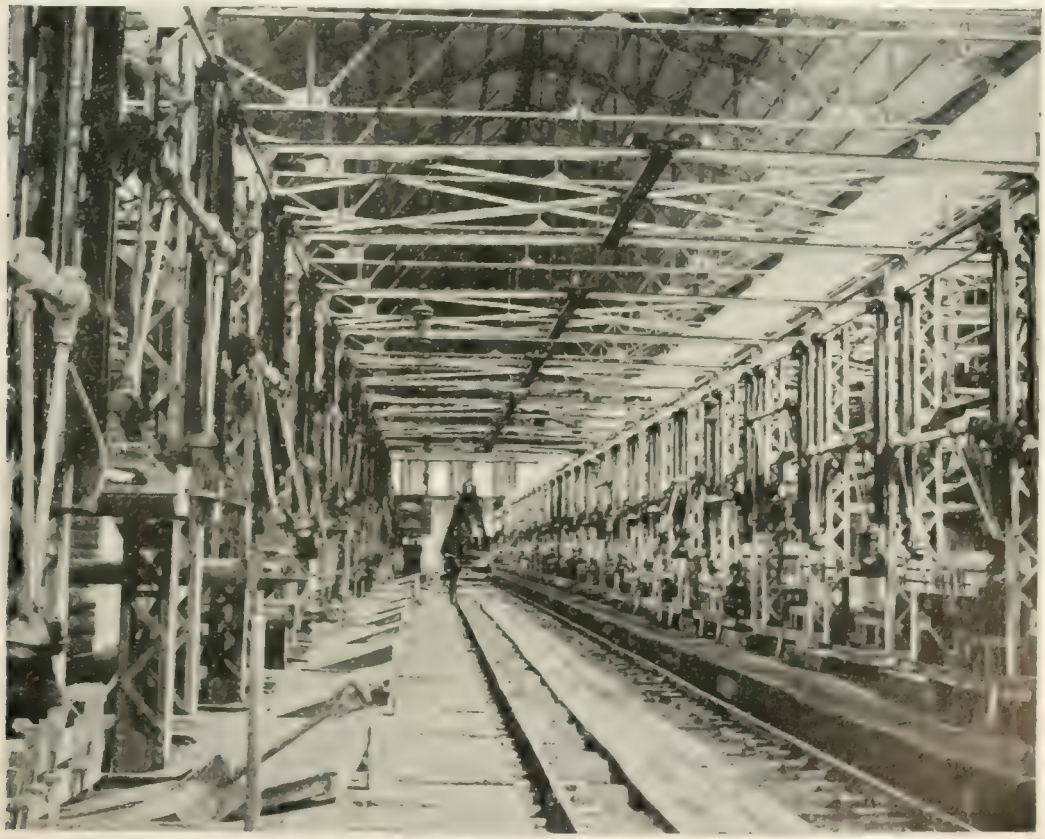


FIG. 5—INTERIOR OF MARBLE MILL SHOWING GANG SAWS IN OPERATION

This is an all steel building, and modern in every respect. The motors and shafts are at the rear of the gang saws.

bed with its own weight only, but if one end is to be cut more than the other, a weight is placed on this end, causing greater friction and faster cutting.

The pieces are rubbed to size by resting them on their edges. When pieces of the same size are being finished, a number of these are clamped together and handled by a derrick. The pieces are measured frequently by steel gauges and removed when the desired size has been reached. Beds are operated singly or in pairs by overhead motors, 10 to 15 horse-power being required for each bed.

In the case of switchboard work, the pieces, still in the clamp,



FIG. 6—ELECTRICALLY OPERATED TRAVELING CRANES

As high as 13 000 blocks of marble, weighing from two to seven tons apiece, have been stored in the yards at one time.

are placed under the head of a polishing machine, which finishes the edges. This head is formed of carborundum or some other abrasive material and revolves rapidly. A constant stream of water hastens the process and also reduces the heat due to friction. By the substitution of a head made of felt and by the use of a polishing powder, composed mainly of oxide of tin, the edges are brought to their final polish. The pieces are then unclamped and taken to a machine which cuts the bevels. The bevels are polished by hand and the faces by a machine. After the finishing is completed, the pieces are assembled on tables for matching, carefully measured and squared, and then boxed for shipment.

ELECTRIC HOISTING IN SOUTH AFRICAN GOLD MINES

A. W. BROWN*

GOLD MINING on the Rand has now passed the stage when mines, or rather claims, are exploited under false pretences with no chance of return to the share-holders. The position and quality of the gold-bearing reef are much better known than formerly, and it has been recognized that in order to make gold mining pay under conditions prevailing on the Rand, it is necessary to deal with large quantities of ore. To this end consolidations have been formed so that many claims can be worked as one mine. This naturally reduces the capital outlay and working costs and enables the use of the most modern equipments for winning the ore and recovering the gold.



FIG. 1—EXTERIOR VIEW, WEST RAND CONSOLIDATED MINES

One such concern is the West Rand Consolidated Gold Mines, Limited, who are at present working one shaft (The East Shaft), and sinking a second on an estate including nearly 2 000 claims situated around Krugersdorp, about 20 miles from Johannesburg. The crushing capacity at the end of 1909 was about 30 000 tons per month, in 1910 about 70 000 tons per month, and with the completion of the new shaft this figure will be greatly augmented.

The West Shaft of this mine which is at present in course of sinking, is a seven compartment shaft and is being driven downwards at an angle of 50 degrees to the horizontal for an estimated distance of 3 000 feet. Sinking was commenced by means of a

*Electrical Engineering Dept., British Westinghouse Electric and Mfg. Company, Ltd.

temporary headgear and two small steam sinking engines, and at the same time an order was placed for two double drum electric

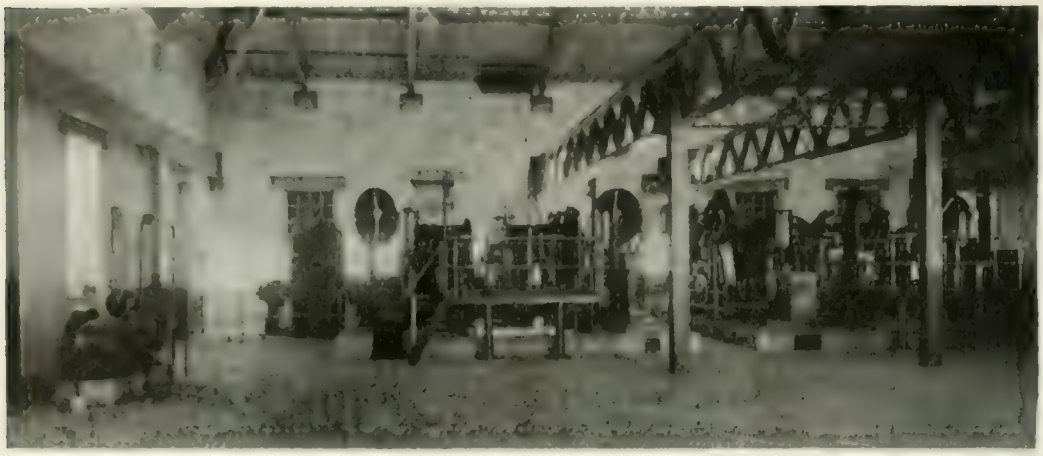


FIG. 2—GENERAL VIEW OF ENGINE ROOM, WEST RAND CONSOLIDATED MINES

winding engines, one suitable for a six ton useful load, and the other for a three ton useful load. By the time the electric winding

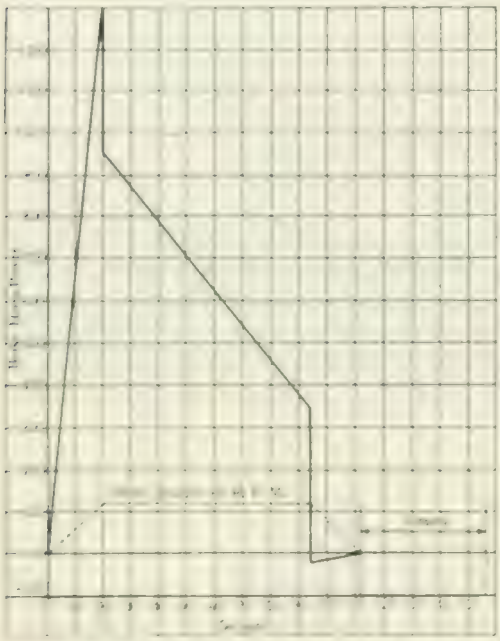


FIG. 3—HOIST NO. 1

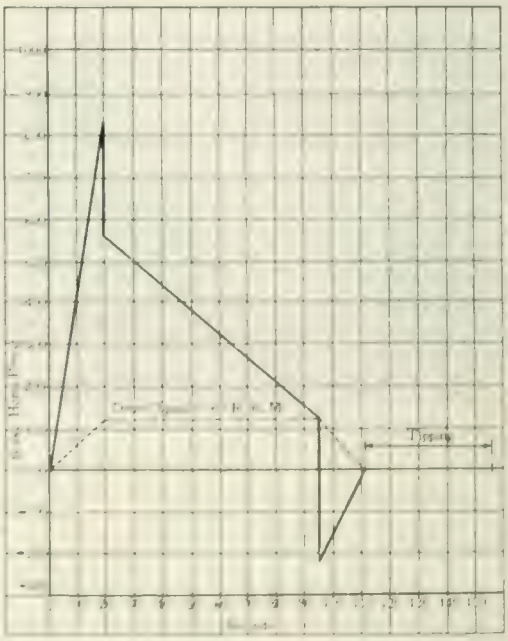


FIG. 4—HOIST NO. 2

Horse power Time Diagrams of the Hoists of the West Rand Consolidated Gold Mining Co., Ltd.

	Hoist No. 1.	Hoist No. 2
Inclination of shaft to horizontal	50 degrees	50 degrees
Length of shaft	3 000 ft.	3 000 ft.
Hoisting speed	2 000 ft. per min.	2 000 ft. per min.
Weight of rock per wind	12 000 lbs.	6 000 lbs.
Weight of skip	7 500 lbs.	5 500 lbs.
Weight of rope	8 500 lbs.	6 000 lbs.
Motor	800 hp. 60 r.p.m.	400 hp. 60 r.p.m.
Motor generator	650 kw, 690 r.p.m.	350 kw, 725 r.p.m.

engines were installed the permanent headgear was completed, and the shaft had been sunk to a sufficient depth to permit of economical hoisting with the electric hoists. The permanent headgear, which is built entirely of steel, together with the winding engine house, is shown in Fig. 1. The engine room is built of brick and is very commodious, whereas the usual engine room on the Rand is of corrugated iron construction. The interior of the engine room is shown in Fig. 2 indicating the positions of the two hoists, and the small compressor for the brakes. The large space in the foreground is reserved for a third electric winding set to be installed when the shaft is finished, and the mine partly developed. The mechanical

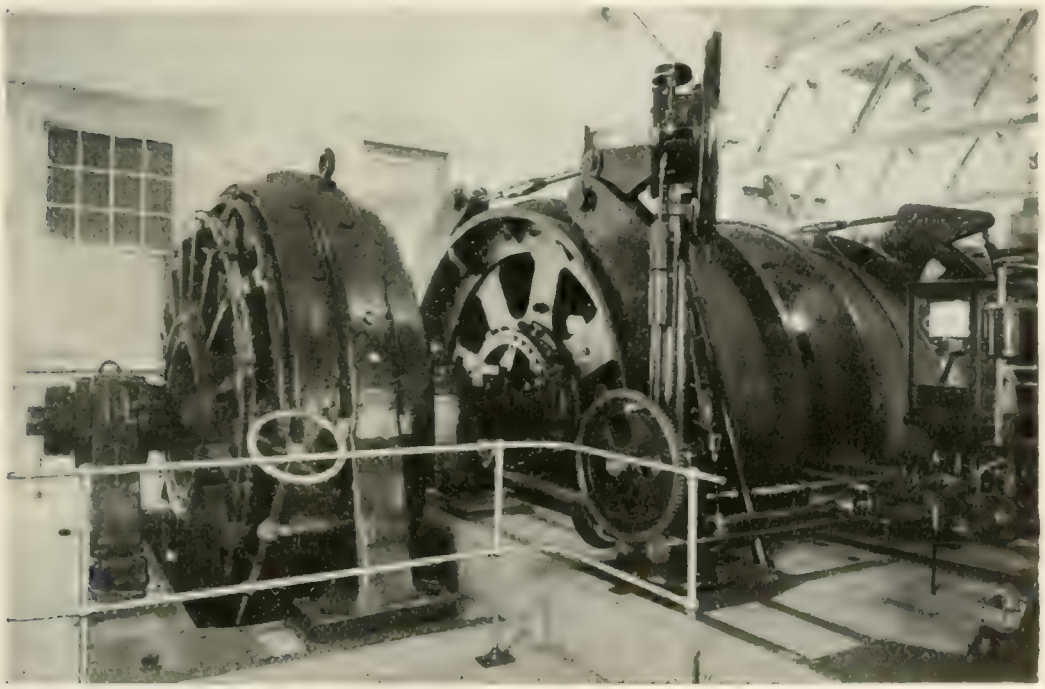


FIG. 5—650 HORSE-POWER, DIRECT-CURRENT, COMMUTATING POLE HOIST MOTOR

equipments of both hoists are almost identical in spite of the difference in the loads. Horse-power time diagrams for these hoists are shown in Figs. 3 and 4 respectively.

Each hoist is equipped with two drums, 10 feet in diameter by 3 feet 9 inches wide, between flanges, running loose on the drum shaft and driven by multi-tooth clutches sliding on hexagonal sections of the shaft. The clutches are operated by hand-wheels on the driver's platform. Post brakes are provided on each drum of the segmental type supported in the center, and applied by weights. Compressed air engines with "Iversen" valve gear are used for releasing the brakes. Interlocks are provided so that the brakes cannot be released on a drum that is not clutched to the main shaft.

Compressed air for operating the brakes is obtained from a small compressor driven through gearing by a 10 horse-power, 3-phase, 50-cycle, 4 500 volt, squirrel-cage induction motor, fitted with automatic starting and stopping gear controlled by the air pressure.

The position of either cage in the shaft is indicated by two dial depth indicators, driven one from each drum through gearing. Each indicator has two pointers, one moving slowly during the entire travel of the skip and the other moving rapidly during the final part of the wind so as to increase the accuracy of stopping. Automatic devices are provided which bring the skips to a slow speed at the tips, and stop the hoist should the skips pass that level, irrespective of any action on the part of the driver.

The electrical equipment is designed for operation with direct-current on the winding motors, which are direct-coupled to the drum shafts, and in each case operate at 60 r.p.m. On hoist No. 1 an 800 horse-power, 600 volt motor, provided with commutating poles, is used. This motor together with some of the mechanical parts is shown in Fig. 5. Hoist No. 2 is provided with a 400 horse-power motor.

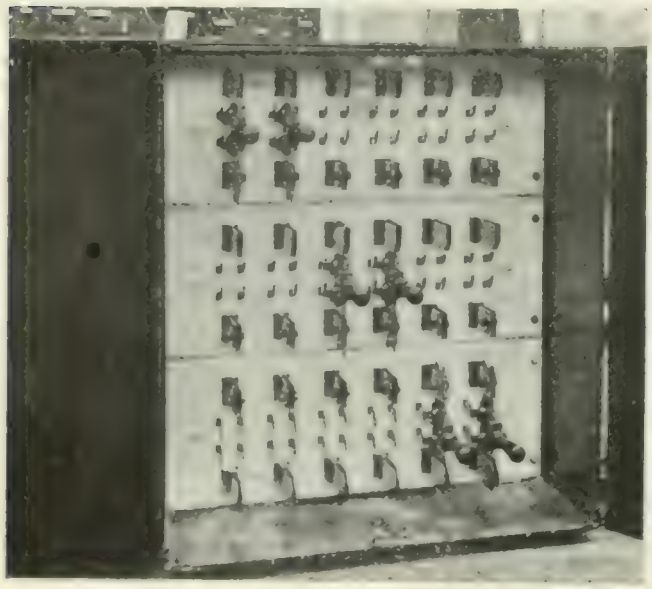


FIG. 6.—SWITCH-BOX, SHOWING SCHEME FOR CONNECTING AND HOIST MOTOR-GENERATOR SET.

The power for the winding motors is obtained from two motor-generator sets, arranged so that either hoist may be driven by either motor-generator, provision also being made for a third equipment in contemplation. A view of the switch-box for transferring from one to the other is given in Fig. 6. Each motor-generator set comprises a 3-phase, 50 cycle, 200 volt, slip ring induction motor, directly coupled to a direct-current generator, and an exciter. The arrangement of the set for No. 1 hoists may be seen in Fig. 7. The alternating-current power for driving the motor-generator sets is purchased from the Victoria Falls and Transvaal Power Company, Limited.

The speed and direction of rotation of the winding engine are controlled entirely by adjusting the strength and direction of the field of the generator in the motor-generator set. This is carried

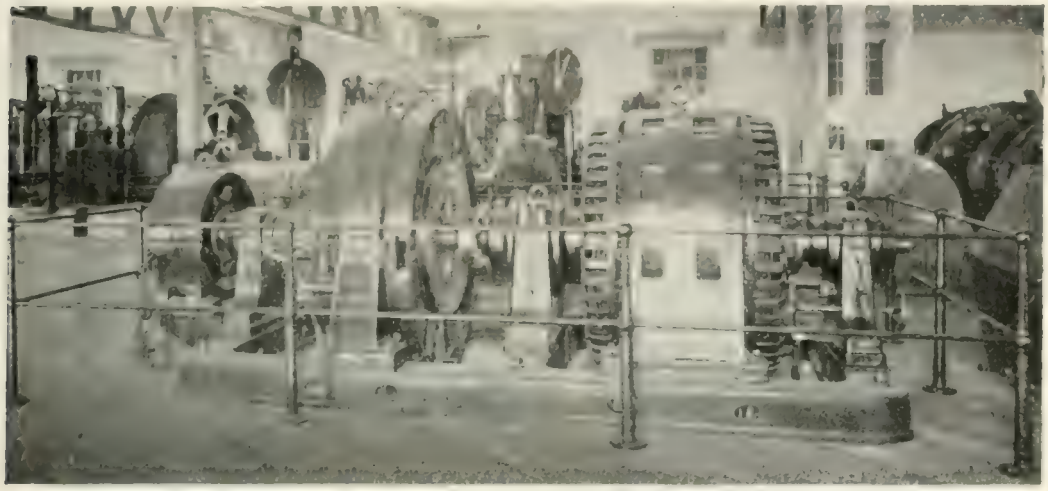


FIG. 7—650 KW MOTOR-GENERATOR SET

Converting power from the lines of the Victoria Falls and Transvaal Power Co., at 50 cycles, three-phase, to direct current for use in the hoist motors.

out by means of the special faceplate controller, illustrated in Fig. 8. By means of this controller any desired speed within the rating of the motor may be obtained in either direction, the speed corrs-sponding closely to the position of the driver's lever irrespective of the load. These controllers are fitted with stops controlled electrically from the bank so that one-half speed cannot be exceeded when men are being raised. An emergency device is provided for each hoist, arranged and connected so that the hoists are quickly stopped in case of overwinding, failure of power supply, failure of exciting current, overloads, failure of air supply or operation of driver's emergency lever. There is thus a safeguard against practically any danger that might arise.

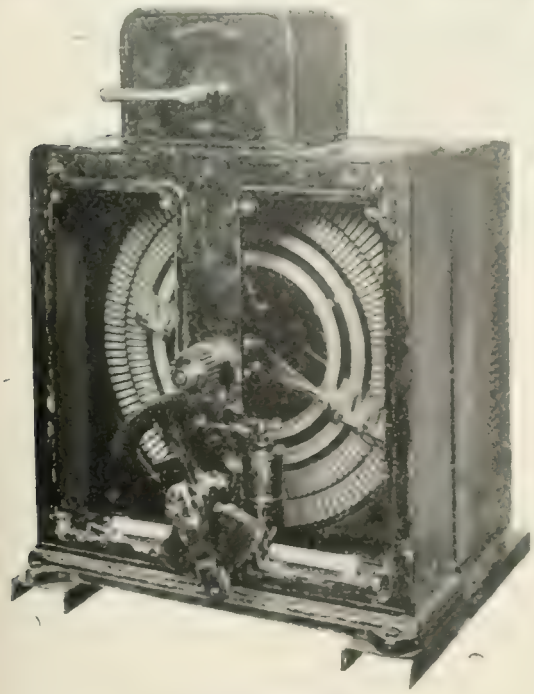


FIG. 8—RHEOSTAT

Giving simultaneous control of the fields on the generator set, and the winding motor.

A four-panel switchboard, illustrated in Fig. 9, is used for

controlling the supply of power to the two winding engines, and is arranged to permit extension when required. It is equipped with one alternating-current and one direct-current panel for each hoist, the former for the motor and the other for the fields of the various direct-current machines.

Although this hoisting system may readily be adapted for use with a fly-wheel, so that no sudden loads are imposed on the power lines, no attempt has been made to equalize the load of these winding engines, since the stations of the Victoria Falls and Transvaal

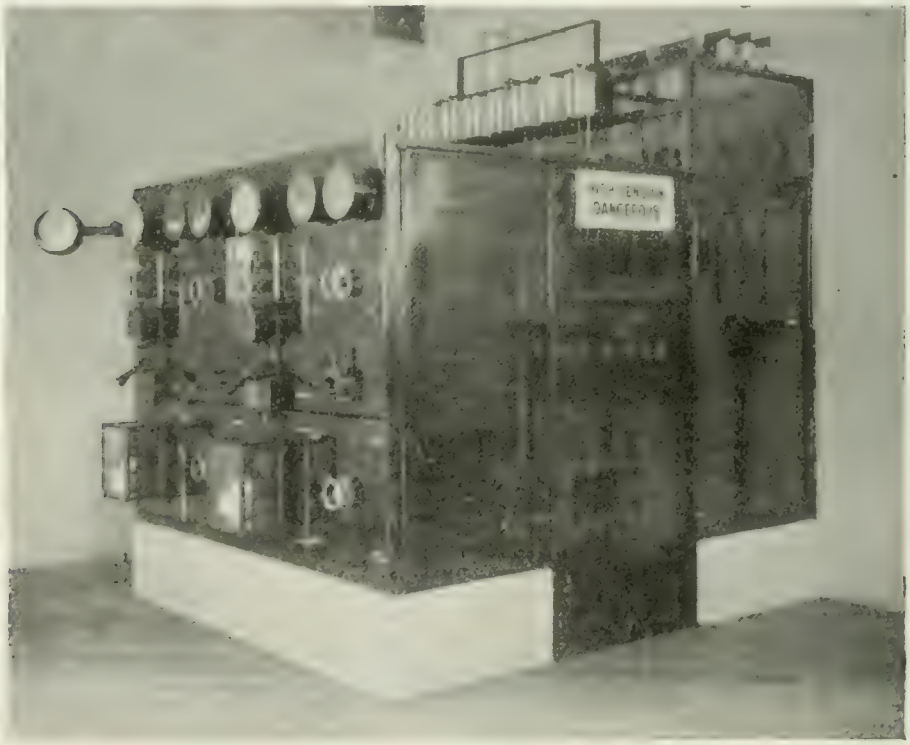


FIG. 9—FOUR PANEL SWITCHBOARD

Two panels are provided for each winding set, one for the control of the alternating current motor, and one for the fields of the two direct-current machines.

Power Company are large enough to be unaffected by the heavy peaks of the large winding engines in use on the Rand.

The use of electricity for driving main shaft winding engines, creates a new problem in connection with shaft sinking. Formerly, the practice was to sink large shafts which were carried down to considerable depths by means of a special headgear, and a pair of small engines. With the advent of the electric winding engine, however, coupled with the practice of purchasing power from a central station, it is no longer necessary to install a steam engine and boiler plant temporarily. The sinking of a large shaft usually oc-

cupies a period of from two to three years, or even longer. It is therefore scarcely permissible to install the winding engine immediately for the full output of the mine, because in addition to the loss on the capital involved, a serious loss is incurred on account of the low efficiency of large hoists when operating at speeds and outputs much below their rated capacity.

One solution of the problem which appears to be eminently satisfactory is that furnished by the electric sinking equipment in the central shaft of the Cinderella Deep Consolidated Gold Mining Company, Limited, Boksburg, Transvaal, Union of South

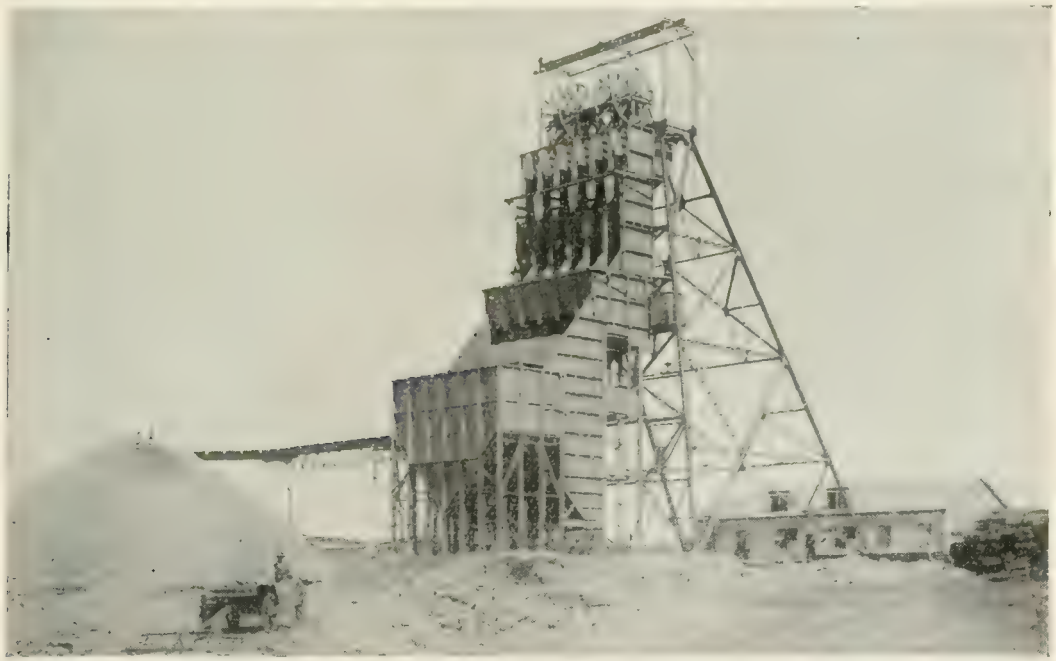


FIG. 10—HEAD GEAR AND ENGINE HOUSE
For hoist at Cinderella Deep Mine, Tobury, South Africa.

Africa. When finished the approximate dimensions will be 43 feet 6 inches wide, 7 feet 6 inches long, and 3 000 feet deep divided into six hoisting compartments, and one pipe and ladder way. The first work carried out at this shaft was to sink for some ten to twelve feet by means of portable steam cranes, and then to install the collar set. As soon as this was done the final headgear was completed, and at the same time two double drum electric sinking hoists were erected in a temporary engine house located between the headgear and the projected site of the main winding engines.

The headgear is illustrated in Fig. 10 which shows clearly the type of construction and arrangement of the ore bins. Figs. 11 and 12 shows the general appearance of the hoists. Details of the hoists and their service are as follows:—

Ropes—Two per hoist, 8 tons (lay, 2 feet, 3 inches wide.
Brakes—Hand operated post brakes on each drum; foot operated band brake on first motion shaft.
Gearing—Double reduction. First motion, double helical power plant steel gear; second motion, machine moulded cast iron gear.
Depth Indicators—Dial type, without overwinding attachment.
Mine Shaft—Vertical, final depth 3,000 feet.
Load—3,000 pounds of rock.
Skip—2,500 pounds.
Ropes—One inch diameter, weight, 4,500 pounds.
Hoisting Speed—1,700 feet per minute.

Each hoist is driven through an electric coupling by a 180 horse-power, 3-phase, 50 cycle, 500 volt, slip-ring induction motor

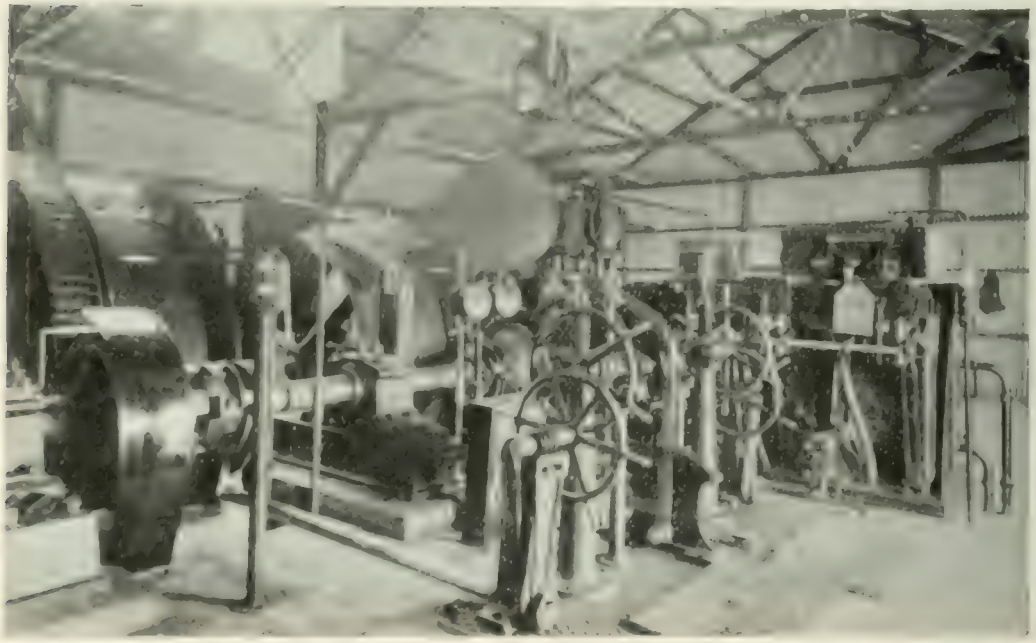


FIG. 11—GENERAL VIEW OF COMPLETED HOIST, SHOWING DRIVER'S PLATFORM

The shaft couplings are shown at the left, and the iron case containing the water rheostat at the extreme right

capable of carrying a load of 450 horse-power for short periods. Power is obtained from the high tension lines of the Victoria Falls and Transvaal Power Company, Limited, and transformed to 500 volts for the hoists and auxiliary apparatus. The control of the hoist is effected by liquid rheostats which can be seen in Figs. 11 and 12.

The especial advantage of this controller lies in the arrangement for automatically limiting the rate of acceleration. The general principle of this type of control is indicated in the diagram, Fig. 13. The controlling lever, *cl*, serves to manipulate through

bell cranks, both the reversing switch D, for the stator, and a movable sluice gate, P, which regulates the height of the liquid in the tank K. In this tank are suspended three stationary electrodes B connected to the rotor terminals. The resistance of the rotor circuits is determined by the height of the liquid, which is under the direct control of the operator. The liquid is kept in constant circulation by means of a motor-driven circulating pump N, and is cooled by means of cooling coils T in the bottom of the tank. The solution is not mixed with the cooling water, but is used over and



FIG. 12.—GENERAL VIEW OF HOIST ROOM
Showing winding motor at the Cinderella Deep Mine.

over again, requiring only occasional replacing of the evaporated water. The circulating speed of the liquid can be regulated by means of the valve S. The operator is thus not able to cut out the rotor resistance too fast. He can fix the position of the sluice gate when starting but the liquid is only gradually raised to this level, according to the pump speed and the opening of the regulating valve. The hoists are stopped, started, and reversed by means of these controllers at any speed from zero to full speed in either direction. A main switchboard of three panels is also supplied.

The sinking of this shaft, in common with many others, entails a good deal of blasting. Should the supply of electric power cease while the sinker is starting a blast, his means of escape would be cut off. In order to obviate this danger the power storage set, illustrated in Fig. 14, is used to ensure a certain supply of power sufficient to hoist the sinker out of danger. It consists of a synchronous motor, which may act as a generator, a heavy fly-wheel running in heavy bearings with forced lubrication, an exciter and a starting motor for bringing the synchronous motor to full speed. The synchronous motor is connected directly to the line, and automatic devices are arranged so that a failure of the power supply causes the main circuit to be interrupted. The power for driving the hoist is then derived from the flywheel. In this case the generator is of 150 kw capacity, running at 750 r.p.m. and the flywheel, in slowing to 375 r.p.m., furnishes sufficient energy to run the set light for five minutes and then hoist a load of 700 pounds in the skip through a distance of 400 feet, thus bringing the sinker out of danger. The power storage set is only in operation during the blasting period and seldom for more than a half hour at a time, three times in twenty-four hours. The manner in which it is operated is as follows:—

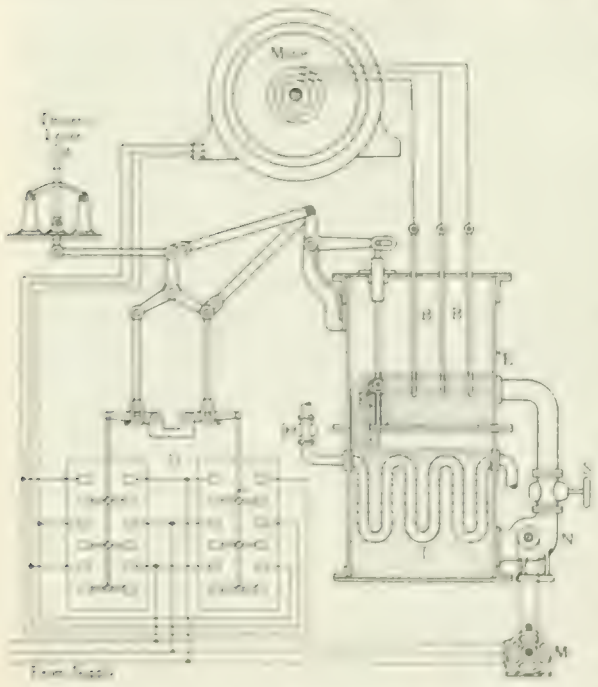


FIG. 13.—DIAGRAM OF LIQUID CONTROLLER

When all the shot holes are drilled, the shaft is emptied and the sinker descends to charge the holes. About fifteen minutes before he is ready to light the fuses, the sinker sends a special signal to start the power storage set. Another signal is sent as soon as he is ready to fire the charges, and the engine driver raises and lowers the skip about two feet to show that all is right. The sinker then lights the fuses, gives the hoist-away signal, and is carried out of danger whether the power supply has failed or not. The value of the power storage set is shown by the log kept on the mine. It is recorded that in five months seven interruptions occurred, one

being during blasting, yet in every case the skip was brought to safety. The value of this feature cannot be exaggerated, while the knowledge that their lives are adequately safeguarded inspires the men with an easy confidence in working, which more than compensates for the cost of installation. These interruptions of power

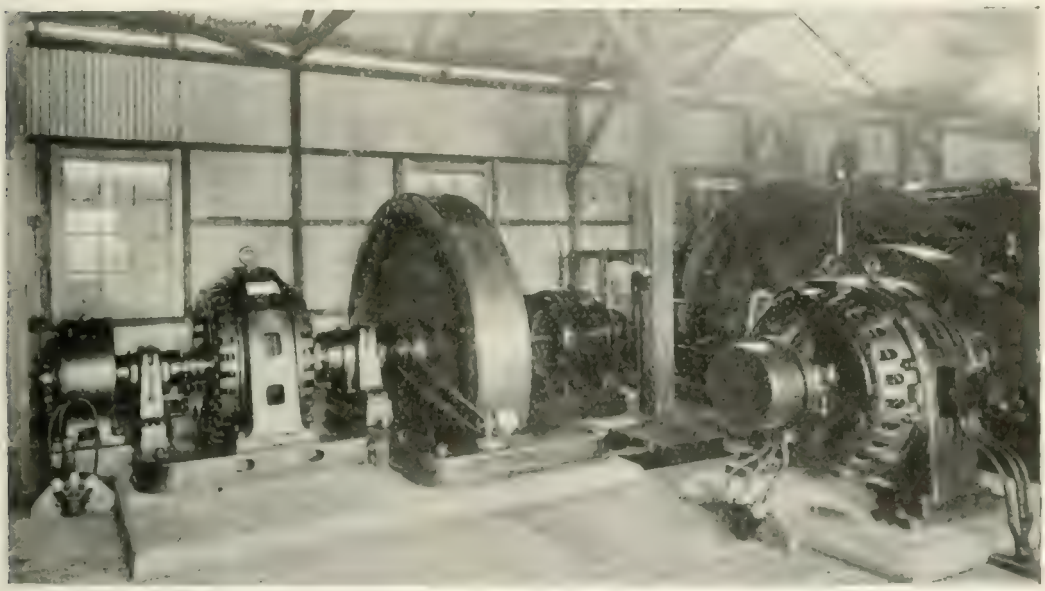


FIG. 14—POWER STORAGE SET AT THE CINDERELLA DEEP MINES

are due, of course, to the great difficulties under which the Victoria Falls stations operate, for there are few places in which thunderstorms are so violent and so frequent. These difficulties would not be experienced to such a degree in countries having a more equable climate.

ELECTRICALLY OPERATED LOCOMOTIVE CRANES

E. P. GRANT

A TYPE of apparatus which is being thoroughly brought into use in the modern tendency toward greater efficiency in railroad and industrial shop operations is the electrically operated locomotive crane, by means of which the loading and unloading of freight cars and miscellaneous hoisting of various loads is being accomplished much more rapidly and easily than heretofore and with a very material saving of labor. The locomotive crane may be defined as a traveling crane operating usually,



FIG. 1.—ELECTRICALLY OPERATED LOCOMOTIVE CRANE LOADING COAL FROM STORAGE PILE TO CARS AT THE YARD OF THE NORTHERN OHIO & OHIO TRACTION COMPANY, AKRON, OHIO.

but not always, upon railroad tracks and having the functions of hoisting, running in a full circle, traveling along the track or railway under its own power, and loading or shifting cars and trucks. Whenever weights in considerable amounts are to be lifted, a crane of this type can usually be employed to advantage.

The type of crane shown in Figs. 1 and 2* has proven very useful for miscellaneous hoisting work of all kinds. Ordinarily this particular hoist is used with a grab bucket for loading coal or ore

*The engravings for this article were furnished by the Brownhoist Locomotive Crane Company, Cleveland, Ohio.

from stock piles into freight cars or vice-versa. This type of crane is, however, susceptible of a wide variety of uses. It can be equipped with a magnet and used in railroad terminals, steel yards, and wherever iron or steel, especially in rough form, such as pig iron or scrap, is to be handled. A power shovel attachment makes the crane suitable for excavating work in trench digging, stone quarries, handling of ashes, etc., while a drag scraper bucket is sometimes more applicable in ditch or sewer excavations. An automatic grapple for wood has been developed by means of which a



FIG. 2—SAME CRANE AS SHOWN IN FIG. 1, SHOWING THE OPERATION OF THE DOUBLE DRUM, TWO-TON HEAD BUCKET

The trolley has been omitted from this crane and a twin cable is laid along the ground and carried directly into the side of the car. This method is satisfactory where the range of travel of the car is not great, and an overhead trolley wire would interfere with the operation.

number of small timbers can be handled simultaneously, and quite a number of cranes are being used around lumber yards or in logging camps.

The hoisting, lifting of the boom, rotating of the cab and propulsion along the tracks is accomplished by means of a single 60 horse-power, 470 r.p.m., series-wound mill-type motor through suitable clutches. The motor is controlled by a standard industrial, drum type control and the whole apparatus is protected by a railway type circuit breaker. The hoisting is accomplished by means of a friction clutch and a train of spur gears. Suspending and low-

ering is accomplished by means of a band brake on the drum. The boom hoist drum raises and lowers the boom for handling loads at different radii through a train of gears by applying a jaw clutch. The hook is held in position by a worm gear. The rotating gear, for slewing the cab either way, is regulated by means of two friction clutches and a train of spur and bevel gears and is independent of the direction of rotation of the motor. Traveling is done through a gear and regulated by means of a friction clutch and a train of gears. The direction of travel is regulated by the rotation of the motor.

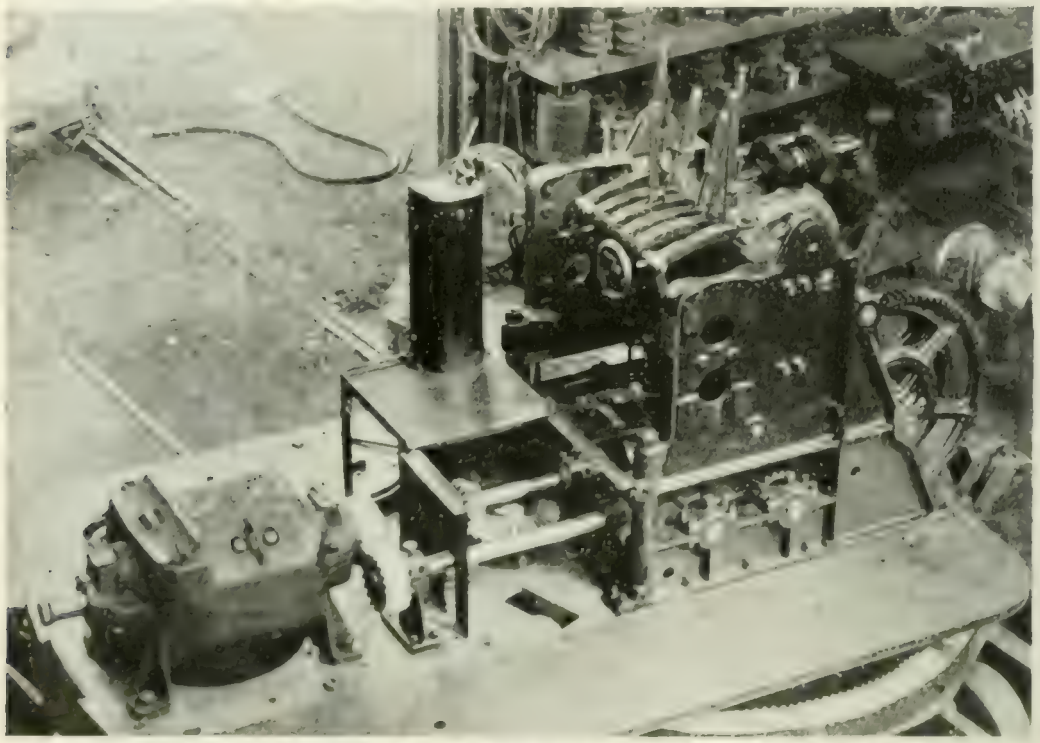


FIG. 3—OPERATING PLATFORM OF ELECTRIC LOCOMOTIVE CRANE

Part of the platform has been removed to show the gearing. The controller is a standard reversing drum type with grid resistors. The clutches, operated by the levers at the driver's right, are of special type, the grip being accomplished by expanding a square helical spring against the inside of a steel sleeve. They work easily and without shock, no matter how suddenly applied.

Hoisting, slewing and traveling can be done simultaneously. One man controls all of these operations from an elevated platform, where all levers and handles are grouped, as shown in Fig. 3. The speed of hoisting at the full rated load is 100 feet per minute, or 150 feet per minute with an empty hook. The rotating speed is at the rate of four revolutions of the car per minute with a full load on the boom, and seven revolutions per minute empty. The car can be propelled along a level track without load at a rate of 600 feet per

minute, or about seven miles per hour and, while exerting a draw-bar pull of approximately 7 600 pounds, at the rate of six miles an hour. This is equivalent to handling six or seven cars on a level track. The efficiency of operation of this type of crane depends materially upon the operator and the conveniences that are provided for him.

The safe loads of this crane, as given in Table I, refer to loads that can be handled at the various radii without upsetting the crane when in free and running order and assuming that eight tons of ballast are used in the truck to give the required stability. The ballast is usually made of the punchings from boiler or structural shops or scrap iron. Four track clamps, two at each end of the track, are bolted to the structural frame and can be quickly clamped to the track in order to increase the lifting capacity when required,

TABLE I—SAFE CAPACITY OF THE CRANE IN TONS

Tons	Radius—ft. (Standard 38 ft. Boom)	Rail to Hook Block
15	10	31 ft.
10	12	32 "
9	15	34 "
6	20	33 "
4.5	25	31 "
3.5	30	28 "
2.5	35	22 "
2	40	12 "
1	50 (Spec. 50 ft. Boom.)	25 "

or to hold the crane when working on a grade. Additional capacities can be obtained by applying stability wheels, special counterweights or both. The approximate working weight of the crane is as follows:

Crane	25 tons
Ballast in truck	8 tons
Weight of motor	3 875 pounds
Weight of controller and resistance, approx.	350 pounds

The crane truck is made of a heavy center casting connected to a rigidly braced structural steel frame, which is mounted on four heavy car wheels. The center casting has a bored vertical bearing for the hollow center or "king" pin and bronze bushings for the bearings of the longitudinal shaft. The structural frame is riveted together with beams and plates. The space between these members is used for ballast. The rotating base consists of a single casting, which supports the machinery and structural platform on each side

in such a manner as to allow the operator to get around and reach any part of the machinery without leaving the cab. Plow steel ropes are used exclusively for both the main and the boom hoist.

In some installations the electric current is brought to the crane by means of a flexible cable which enters directly into the side of the trucks. In the majority of cases a standard trolley is used in order to allow the crane to be self-propelling and to be useful at any place along the track of an electrically operated railway company. A type of trolley which is suitable for low trolley wires such as are used around mines and on some ore docks, is shown in

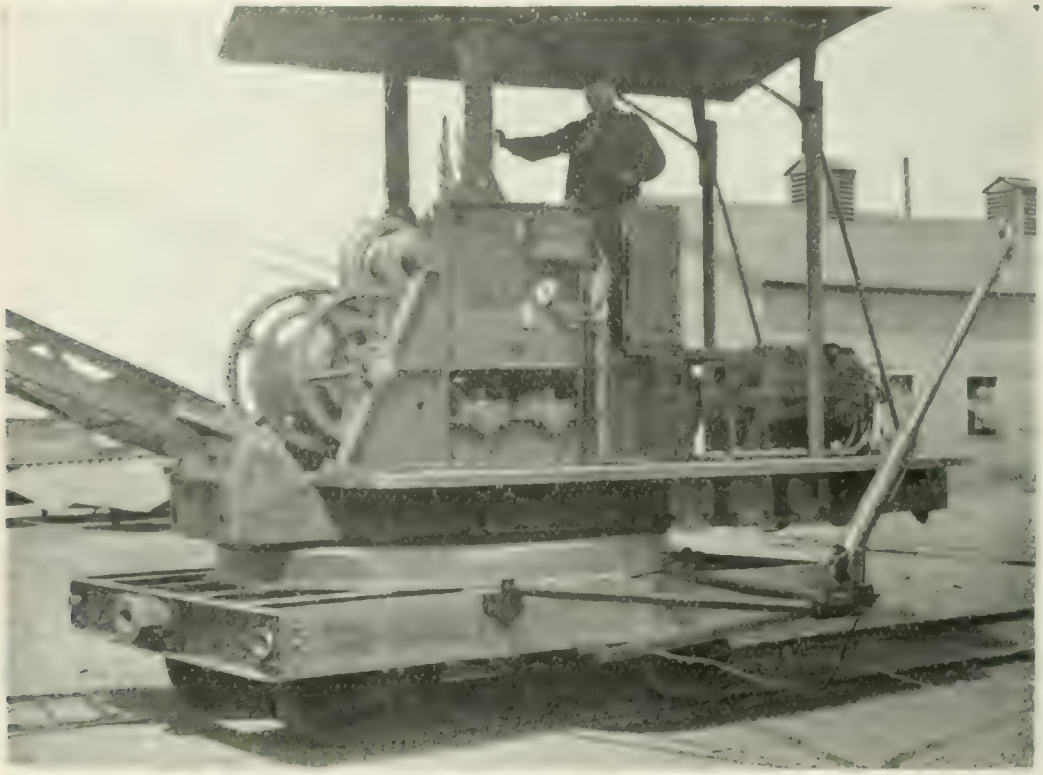


FIG. 4—OPERATOR'S STATION, SHOWING CRANE EQUIPPED WITH MINE TYPE TROLLEY POLE, FOR USE AROUND MINES AND ORE DOCKS

Fig. 4, the base of the trolley support being extended sufficiently far from the side of the crane to clear the rear end of the rotating structure when the latter is at right angle with the track.

A type of railroad crane which has proved very useful to several of the larger interurban electrical railway lines is shown in Fig. 5. This crane is used by the Illinois Traction Company for wrecking purposes and for loading freight cars around the terminal and for coal handling, with a grab bucket. It is equipped with a single railway type motor of 100 horse-power capacity, which furnishes power for performing all the necessary operations through clutches, as previously explained. This motor is of the size and

type which is standard for the interurban cars of this system, so that no spare parts need be carried in stock. The capacity of this crane is 43 500 pounds at ten feet radius, 13 400 pounds at 25 feet

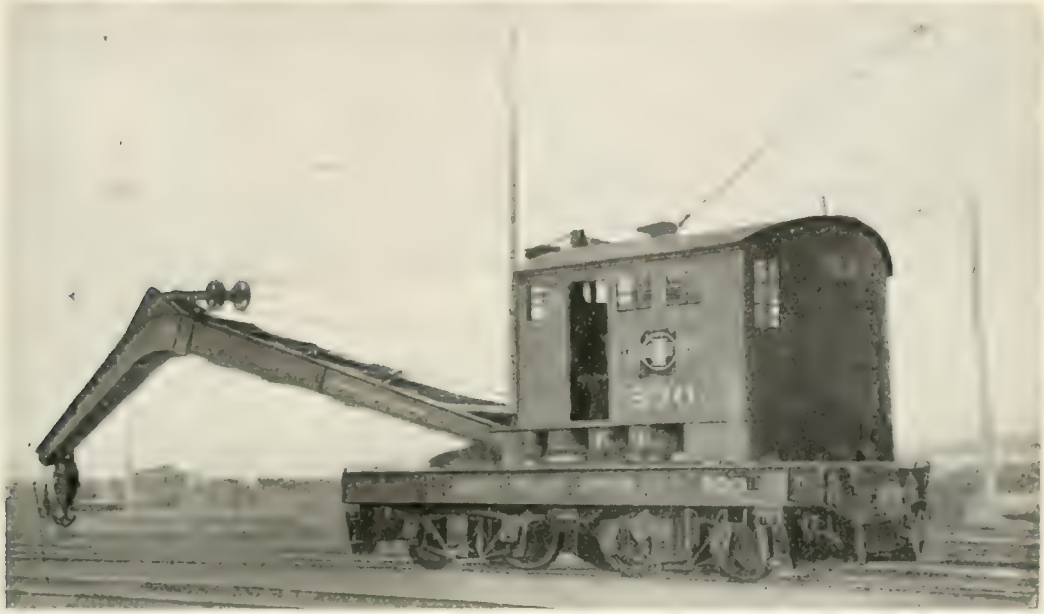


FIG. 5—ELECTRICALLY OPERATED LOCOMOTIVE CRANE, USED BY THE ILLINOIS TRACTION COMPANY, MAINLY FOR UNLOADING FREIGHT AND COAL IN THEIR YARDS AT DECATUR, ILL.

This Company also operates a yard crane similar to the one shown above, except that a standard 38 foot boom of the type shown in Figs. 1 and 2 is used.

radius and 7 100 pounds at 40 feet radius, and the maximum self-propelling speed of the car on level track is ten miles per hour. Out-riggers and track anchors are provided for steadying the wrecker when the boom is swung to one side.

RELATION OF FLYWHEEL AND MOTOR CAPACITY FOR INDUSTRIAL LOADS

S. A. FLETCHER and CHAS. R. RIKER

WHEN a non-reversing motor is subjected to sudden fluctuations and overloads of short duration, with periods of light load between the peaks, a flywheel of correct proportions will relieve the motor and the supply circuit of a large part of the fluctuations. If the motor is also properly chosen with reference to the flywheel and load, its size may be materially reduced, and hence the average load will be nearer its rated capacity, thus making the average efficiency materially better. The motor should have a considerable drop in speed from no load to full load so that the flywheel and motor will slow down as the load comes on, since a flywheel gives up its stored energy as its speed is decreased. The advantage of the flywheel may be nullified by the use of a motor which tries to maintain a constant speed. This requires, therefore, for direct current, a compound-wound motor with a 10 to 25 percent speed drop, and for alternating current either a high resistance end ring, squirrel-cage motor or a wound secondary motor with a speed drop of from 8 to 20 percent. Standard squirrel-cage motors for non-flywheel load have closer speed regulation and are not so satisfactory for this class of service.

The interaction between flywheel and motor may be expressed by equations, which, if average results only are desired, are comparatively simple. A complete solution, however, involves more complicated equations. The authors have reduced these to graphical form in the hope of affording assistance in the solution of many problems which now go unsolved, or are merely guessed at, for the lack of a ready and reliable means of determining the exact relation between a given flywheel and a motor of given speed-torque characteristics driving a given load.

The energy stored in a flywheel is expressed by the fundamental formula:—*

*Letters used in equations and in the charts in this article have the following significance:—

E = Energy in the flywheel.
M = Mass of the flywheel.
W = Weight of the flywheel in pounds.
V = Velocity of center of gyration of flywheel in ft. per sec.
V_1 = Initial velocity of center of gyration of flywheel in ft. per sec.
V_2 = Final velocity of center of gyration of flywheel in ft. per sec.
k = Radius of gyration in feet.
r = Outside radius of rim expressed in feet.
r_1 = Inside radius of rim expressed in feet.
N = Revolutions per minute.
N_1 = Initial speed in revolutions per minute.
N_2 = Final speed in revolutions per minute.

$$E = \tfrac{1}{2} MV^2 \text{ whence}$$

$$\text{Hp-sec} = \frac{WV^2}{35420}$$

and the energy delivered for a given change in speed is

$$\text{Hp-sec} = \frac{W(V_1^2 - V_2^2)}{35420}$$

The distance of the center of gyration from the center of gravity is called the radius of gyration. For a flywheel composed of a solid disk, this distance is determined by the formula $K^2 = 0.5\,R^2$. For a flywheel with rim and web, the flywheel effect of each must be calculated separately and added. The radius of gyration is determined for the rim, from $K^2 = 0.5\,(R^2 + r^2)$, and for the web, from $K^2 = 0.5\,r^2$. For a flywheel with rim and arms the calculation of the exact value of K for the hub and arms is difficult. For standard designs it will be found to closely approximate $K^2 = 0.33\,r^2$.

In order to use these values, the expression for horse-power-seconds may be simplified by substituting for V its value in terms of the radius of gyration. Thus the square of the velocity is, —

$$V^2 = \left(\frac{2\pi\,KN}{60}\right)^2 = 0.011\,K^2N^2$$

The equation for the energy delivered by a given drop in speed is then

$$\text{Hp-secs} = 0.000\,000\,31\,WK^2\,(N_1^2 - N_2^2)$$

The weight W may be figured from the volume of the iron by considering the weight as 450 pounds per cubic foot for cast iron, 480 pounds for wrought iron and 490 pounds for steel. Care must be exercised not to exceed the safe peripheral speed of a flywheel. With cast iron this peripheral velocity must not exceed 5 000 to 6 000 feet per minute; with cast steel 10 000 feet per minute is the maximum allowable, and special laminated flywheels built of thin boiler plate material riveted together may be run from 10 000 to 25 000 feet per minute. A speed much used in this last type of flywheel is 20 000 feet per minute. If the flywheel effect is not great enough and the speed cannot be brought any higher, the weight may be increased by increasing the width of the rim.

---

t = Time in seconds.
T = Torque expressed in pounds at one foot radius.
T_1 = Torque of load.
T_2 = Accelerative torque of motor at end of peak load.
D_1 = Speed drop of flywheel in r.p.m. below synchronous or no-load speed at beginning of peak load, on the assumption that the drop is in direct proportion to the load.
D_2 = Speed drop at end of peak.
D_3 = Speed drop if motor were to carry entire load, based on same assumption as above.
D_4 = Speed drop at friction load. If there is time for the motor to fully accelerate the flywheel between peaks, D_4 and D_1 are the same.
$S_1 = D_3 - D_1$ = Change in speed if motor were to carry entire load.
$S_2 = D_2 - D_4$ = Change in speed required to fully accelerate the flywheel at end of peak.

Since the power required is often expressed in terms of torque, it is sometimes more convenient to use a formula involving the torque which a flywheel will develop for a given time. This may be derived by substituting in the preceding equation the fundamental formula,—

$$Hp = \frac{\text{lbs} \times \text{av. ft per min.}}{33\,000} = \frac{T(N_1 + N_2)}{10500}$$

By substitution,

$$T = \frac{0.00329\, W K^2 (N_1 - N_2)}{t}$$

These formulæ give in simple terms, the total energy stored in a flywheel, the total energy delivered during a given change in speed, and the average torque developed by a flywheel during a given change in speed. From these values, knowing the total load, it is possible to calculate the average load on the motor during any given drop in speed. No indication is given, however, of the maximum load on the motor, which may equal the total load, in which case the flywheel might as well be removed.

The torque required must, of course, be determined before a solution of a flywheel problem is possible. No general method can be given which will fit all cases, but a few suggestions as to method of procedure may be helpful. Where a machine is driven by a motor, and has a flywheel, both maximum load and friction load may be determined by suitably damped indicating instruments, or by graphic recording instruments, with rapidly moving paper. If the clock mechanism is too slow it may be disconnected and the paper moved by hand at a constant rate. The length of the load period may be determined from the graphic record, or by means of a stop watch. If the time is too short, the machine may be turned over slowly, and the number of revolutions or the fraction of a revolution of some element during the period that the load is on can be noted. From the speed of this element during normal operation, the time may be estimated. If the machine is already equipped with a flywheel it should be disconnected while the load characteristics are being determined.

Where a machine is equipped with a flywheel, and no motor is available, but it is desired to determine the load characteristics in order to determine a suitable motor, the following method will give a good approximation. Bring the machine up to speed, disconnect it from the source of power and note the time required for the machine and flywheel to stop. The energy initially stored in the flywheel can be calculated from its dimensions and speed, and from

the formulæ previously given the average torque required to overcome friction may be observed. The machine should then be again brought to speed, disconnected from the source of power, and the machine made to perform one or more complete cycles of work, without intermission, under normal conditions. With a tachometer and a stop watch, the drop in speed and the time per cycle should be noted. From these and the dimensions of the flywheel the average torque of the total load may be determined, and by subtracting the friction load, the useful load T_1 may be secured. This method does not ordinarily admit of great accuracy, and is to be recommended only when a trial motor installation cannot be made.

Where the data on the load has been determined, the next step is to find what motor will operate most successfully with the given flywheel* or perhaps what flywheel should be put on in place of the present one. This requires a consideration of the torque required in starting, the maximum load on the motor while running, the time allowed for the motor to accelerate the flywheel in the intervals between the peaks, the time in which the drop in speed occurs and the allowable speed drop which will be permitted in the machine itself. The object to be attained is a fairly even load on the motor with the flywheel taking care of the peaks. The motor must restore to the flywheel as much energy during the light load as the flywheel delivers during the peak, in addition to carrying the friction load, or, in other words, the motor must bring the flywheel velocity back to the original value between each peak or the load on the motor will continually increase with each cycle until this condition is secured.

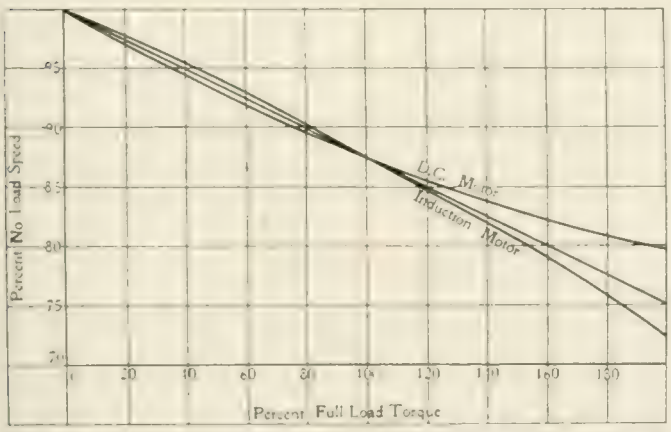


FIG. 1—SPEED TORQUE CHARACTERISTICS OF WOUND SECONDARY INDUCTION MOTOR AND COMPOUND DIRECT-CURRENT MOTOR, COMPARED WITH A STRAIGHT LINE, BOTH MOTORS HAVING A 12.5 PERCENT SPEED DROP AT FULL LOAD

In order to analyze the relations between a given flywheel and a given motor, it is advisable, though not always necessary, to plot a curve or group of curves showing the torque required to overcome

*See article by Mr. R. E. Hellmund in the JOURNAL for Nov., 1910, p. 870.

friction, the total torque, the torque supplied by the motor and that supplied by the flywheel at any instant of time. Such curves are shown in Fig. 2. They are plotted according to the formulæ developed by Mr. H. C. Specht, which have been put in graphic form in Fig. 4. These formulæ are based on the assumption that the torque developed by a motor is in direct proportion to the drop in speed.* That this assumption is entirely warranted within the

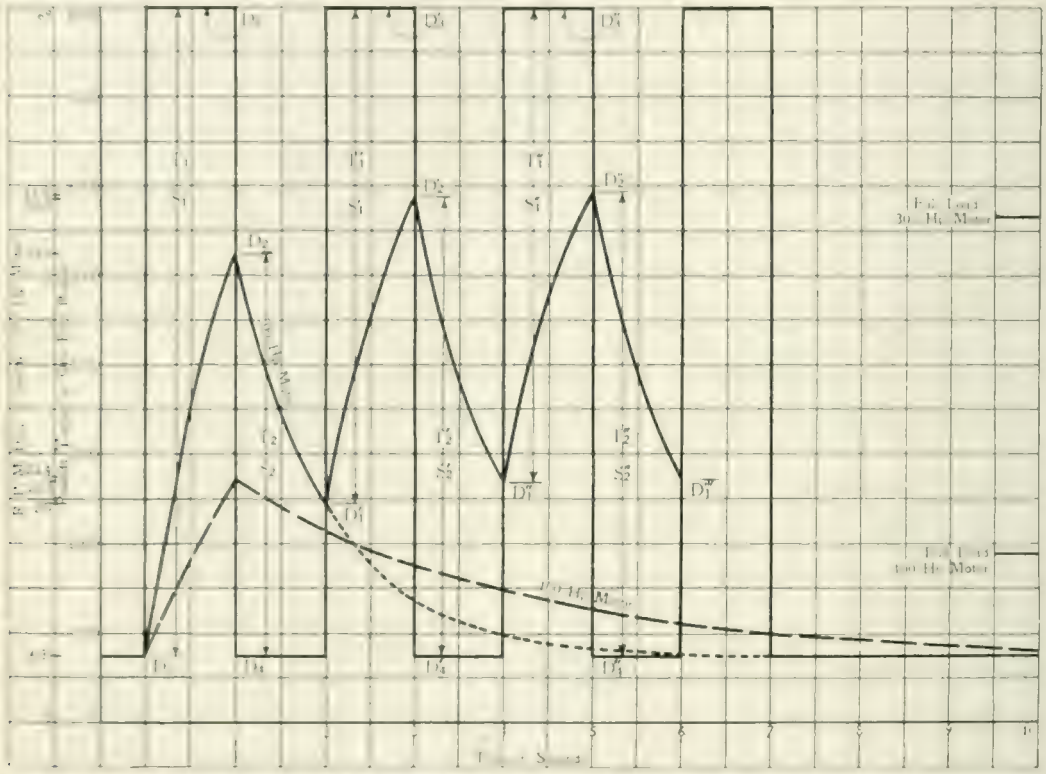


FIG. 2—TORQUE TIME CHARACTERISTICS OF 300 AND 100 HORSE-POWER INDUCTION MOTORS CONNECTED TO SAME FLYWHEEL AND LOAD

Since the speed and torque are assumed proportional, the curves can be considered as plotted to either of the sets of ordinates shown at the left.

normal working range is shown by the curves in Fig. 1.

The values necessary to plot a curve as shown in Fig. 2 are

*Transactions A.I.E.E. June, 1909, p. 870. For those who desire the original formulæ, they are stated here, without derivation. Let v equal the velocity of the flywheel in feet per second at one foot radius at any time v_1 = velocity at beginning of peak, v_2 at end of peak, v_3 velocity if motor carries entire load, and v_4 velocity at zero useful load, i. e., at friction load, and other letters the same as in the article. Then for retardation—

$$t = \frac{v_1 - v_3}{\frac{T_1 g}{\Sigma WK^2 (v_1 - v_2)}} + v_3$$

and for acceleration

$$t = v_4 - \frac{v_4 - v_2}{\frac{T_2 g}{\Sigma WK^2 (v_4 - v_2)}}$$

the torque of the useful load, the torque of the friction load, the dimensions of the flywheel, the drop in speed of the motor at full load, the length of time the load lasts and the time between load periods. The method of using the charts can best be shown by an example. This example does not take into consideration the flywheel effect of the arms of the flywheel nor of the rotating element of the motor which is usually small. For greater refinement these should be added to the WK^2 of the rim. If the flywheel and motor run at different speeds the flywheel effect of the latter must be changed to correspond to the flywheel speed. Thus, if the motor runs at twice the speed of the flywheel, its WK^2 should be doubled before being added to that of the flywheel.

If a useful load of 7 240 pounds at one foot radius, occurring at intervals of one second and lasting for one second with a friction load of ten percent of this amount be assumed, the time-torque curve of the load will be as indicated in Fig. 2. Regardless of any flywheel action, the average of the useful load, plus the friction load, must be carried by the motor. The average useful torque must therefore be one-half of 7 240, since the load is on for one-half the total time and the motor load will equal $3\,620 + 724 = 4\,344$ pounds. If it is assumed further that the speed at this average load should be about 280 r.p.m. and that the motor should not drop in speed more than about 15 percent at full load, a no-load speed of about 330 r.p.m. is secured. This corresponds to a 22 pole, 60 cycle, induction motor (327 r.p.m. synchronous speed). An average load of 4 344 pounds at 280 r.p.m. requires 232 horse-power. To pull the total load would require peaks of 425 horse-power. A 250 horse-power motor will carry the average load easily, but since the heating effect varies with the square root of the mean square of the load, which is greater than the average, and also to allow for emergencies, a 300 horse-power motor will be chosen for a preliminary estimate.

Assume first that the machine is equipped with a six-foot flywheel (36 inches outside radius), 12-inch face and 8-inch depth of rim. The flywheel effect can be calculated from the formulæ previously given, or can be determined from the chart, Fig. 3, as follows:—

Starting with the line representing 36 inches radius, read to the curve representing 8 inches depth of rim, then to the reference line at the beginning of the diagonals, interpolating, where necessary. From this line follow the diagonal to the line representing 12

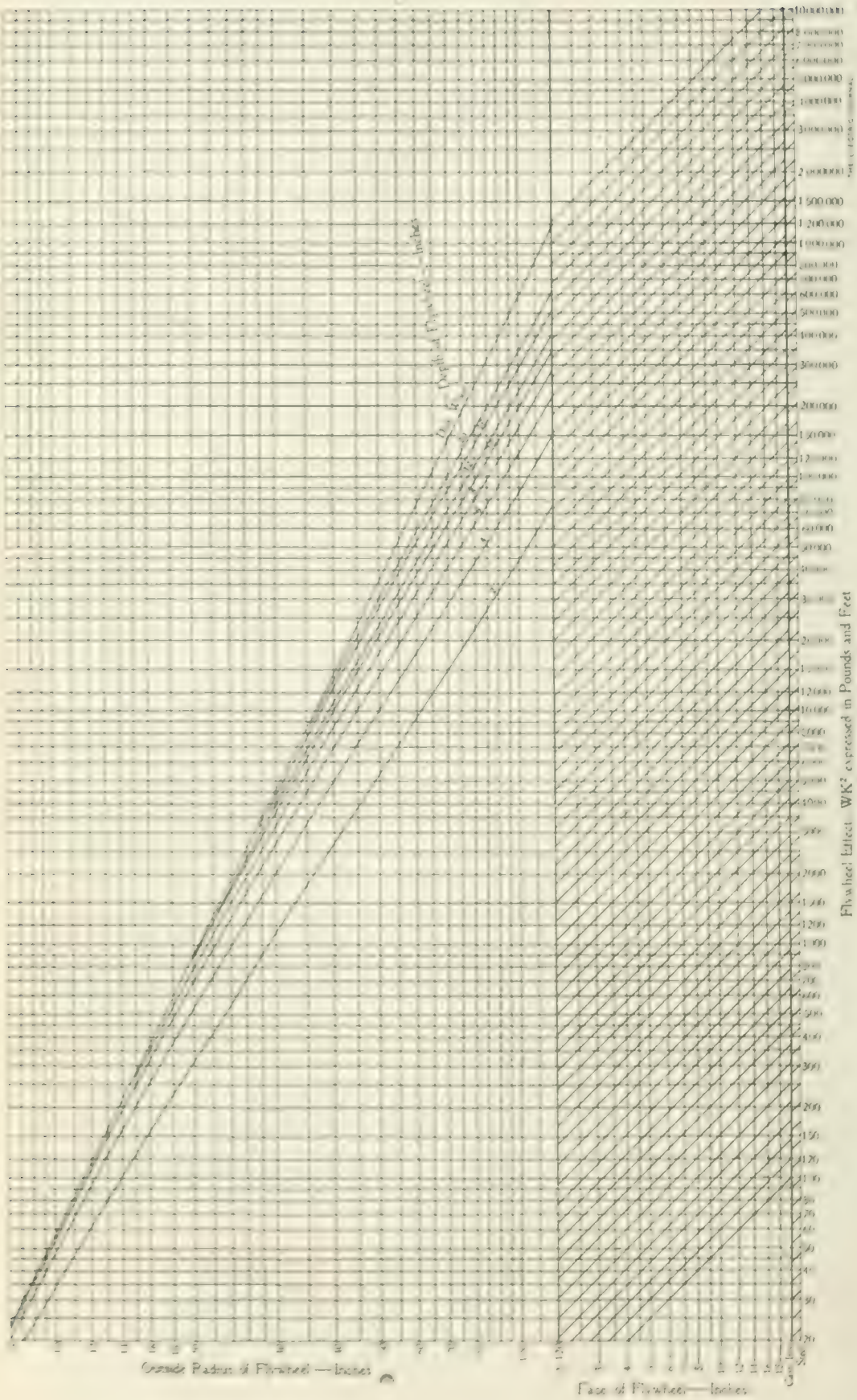


FIG. 3.—DIAGRAM FOR SECURING FLYWHEEL EFFECT FROM THE DIMENSIONS OF A FLYWHEEL

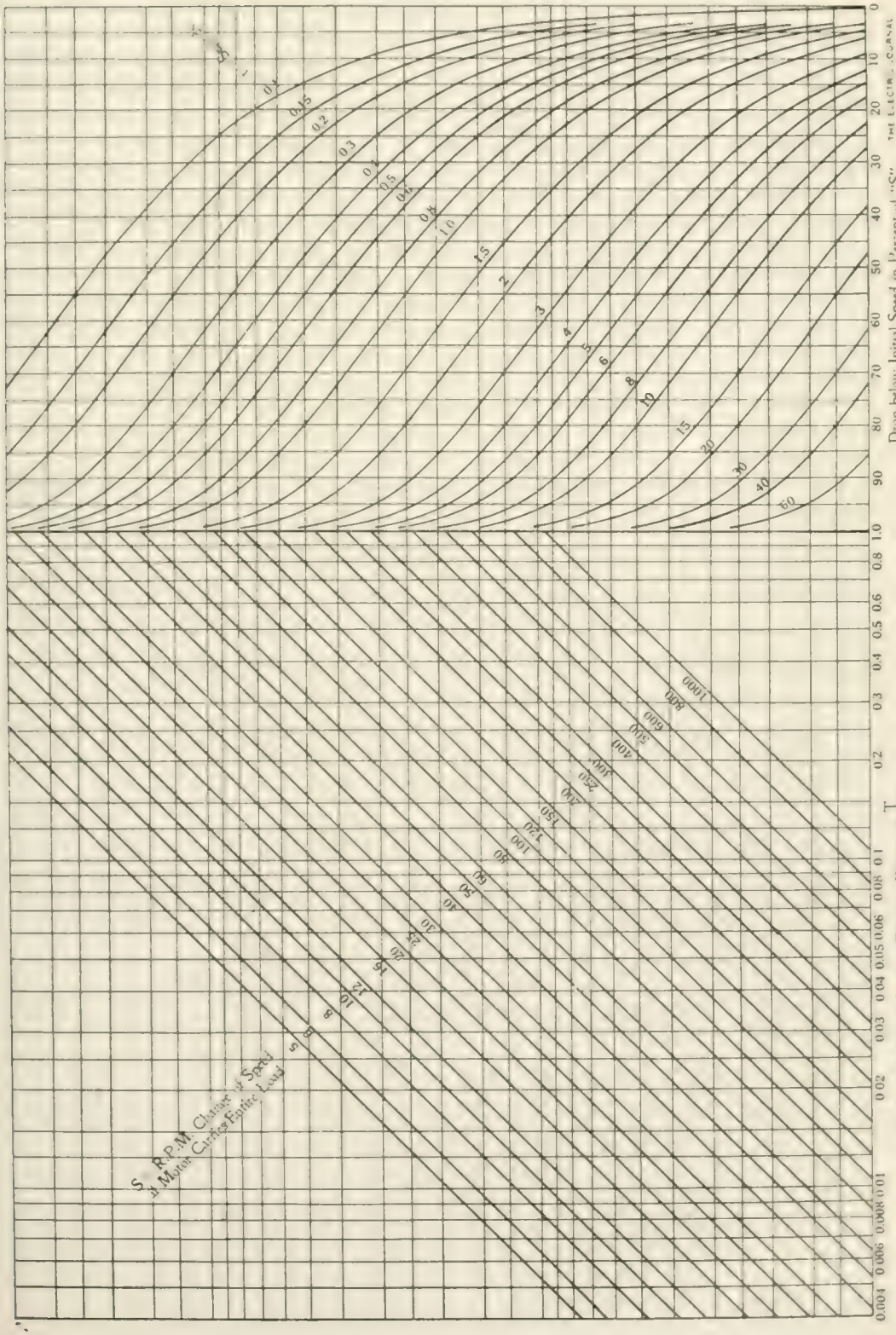


FIG. 4.—DIAGRAM FOR USE IN DETERMINING THE LOAD CHARACTERISTICS OF A MOTOR DRIVING A FLYWHEEL

inches face and then to the reference line representing cast iron. The value opposite this point, 36 200, represents the flywheel effect. If a steel wheel is to be used, from the reference line marked cast iron follow the second set of diagonals to the reference line marked steel, when the flywheel effect for a steel wheel will be given. The values do not include the weight of the arms which ordinarily can be neglecteed, or if desired, seven to ten percent may be added to the flywheel effect of the rim. For extreme accuracy, the values for the arms must be calculated separately. For a disk flywheel, having no arms, the curve marked "Disk Wheel" should be used.

If no flywheel is provided, it is necessary to determine a suitable size. The flywheel effect desired can be estimated from the ratio of flywheel effect to torque of load. In the case worked out above this ratio $= \frac{7240}{36200} = 0.2$. The determination of the ratio to be assumed depends on the characteristics of the load. If the speed variation or the current peaks must be minimized a small ratio, i. e., a large flywheel effect must be chosen, and vice versa. The interval between peaks does not determine the size of the flywheel, but only the size of motor to be chosen. Having assumed a ratio and hence the flywheel effect desired, the dimensions of the flywheel can be determined from Fig. 3, starting at the value of flywheel effect, and reading over to the dimensions. The outside diameter will be limited by the maximum safe peripheral speed. Thus, with the motor speed assumed, 36 inches is about the maximum outside radius which would be safe for a cast iron wheel.

In case the range of this chart is not sufficiently great, the values for face of flywheel can be doubled, and the corresponding values for flywheel effect also doubled, as these two quantities are in direct proportion. This is not true, however, of the other values in the chart.

Having determined the flywheel effect, the chart in Fig. 4 may be used to determine points on the curve. The load curve should first be plotted. If a complete analysis is to be made, a motor load curve, as in Fig. 2, should be plotted. If it is only necessary to determine the maximum load on the motor, which occurs at the end of the peak load, this value only need be solved for. The chart may be used for the curve of retardation or of acceleration, the only difference being in the values of S and T used. For retardation, while the flywheel is carrying part of the load, S_1 and T_1 are used, and for acceleration, S_2 and T_2. The relative

values of these terms are shown very clearly in Fig. 2. A 300 hp motor with 15 percent slip at full load will then give a speed drop of 6.3 r.p.m. (D_1) below synchronous speed, with a friction load of 724 pounds torque, and a drop of 69 r.p.m. (D_2) with a peak load of $7240 + 724 = 7964$ pounds torque. For the example chosen $\frac{T_1}{WK^2} = \frac{7240}{36\,200} = 0.2$ and $S_1 = 69 - 6.3 = 62.7$ r.p.m. Following the line 0.2 to the diagonal 62.7 (interpolated) and then along the horizontal to its intersection with the various lines representing time, the drop of the motor at various time intervals can be determined in percent of S_1. Since the torque is in proportion to the speed drop, these percentage values may also be considered as torque, expressed in percent of T_1, and may be plotted on whichever basis is more convenient. This gives the curve of retardation during the first second, plotted above the line of friction load. For convenience, the torque or the speed drop corresponding to the friction load may be added to the values secured and the curve plotted above the zero line as a base.

The curve for acceleration is secured in an exactly similar manner from the same chart, except that the values chosen are T_2 and S_2, as defined previously and as shown in Fig. 2, and the values are plotted downward from the maximum torque or speed drop reached on the retardation curve, indicated at D_2. For convenience these values may be subtracted from this maximum value (equal to S_2 plus friction drop or T_2 plus friction torque) and plotted above the zero line as a base. As shown by the dotted acceleration curve, the motor in this case will bring the flywheel back to approximately friction load speed in about six seconds.

The area of the load curve above the retardation curve is proportional to the power supplied by the flywheel. The area between the friction load and the retardation curve represents the power supplied by the motor during retardation, and the area between the friction load and the acceleration curve represents the power supplied by the motor to the flywheel during acceleration. This area must equal the area representing the output of the flywheel during retardation, in order to have the cycle exactly repeated. If, however, the peak load is repeated after an interval of one second, these areas are not equal and the motor will carry a much heavier load at the beginning of the second peak than at the first. S'_1 will then equal $D'_2 - D'_1$ and T'_1 will be the value represented by the difference between the torques at the speeds D'_2 and D'_1 as indi-

cated in the diagram. In a similar manner the succeeding values of S and F are determined. The maximum load values keep increasing until the power supplied by the flywheel during the load period exactly equals that supplied to the flywheel during the interval between peaks, when the values become constant.

From the first acceleration curve it is evident that a much smaller motor will be satisfactory if the interval between peaks is sufficient. The curve which is plotted in the same diagram for a 100 horse-power induction motor, having the same speed and per-cent slip at full load, i. e., three times the slip for the same load, shows that the flywheel carries the greater part of the peak, the motor being momentarily overloaded about 45 percent. In this case, however, approximately 15 seconds are required between peaks to allow the smaller motor to bring the flywheel back to speed.

The diagram, Fig. 4, may be used for the analysis of any case where a load is driven by a flywheel and a prime mover whose drop in speed is practically proportional to the load. This includes most steam and gas engines, as well as electric motors. It is not suitable for a flywheel alone, nor for any case except where the flywheel is gradually relieved of the load by some prime mover, and hence cannot be used in the case of a flywheel designed to regulate the speed of a prime mover, as, for instance, a gas engine driving a generator, as the shape of the curve is quite different in this case.

In general, the selection of a suitable flywheel represents a compromise between the losses occurring in the motor, and the friction and windage of the flywheel, considering the speed requirements of the load and the fact that the heating of a motor is greater with a fluctuating load than with a more uniform load of the same average power requirements. No one solution can be considered the only possible satisfactory one, as the load curve may be made smoother, either by increasing the flywheel effect, or by increasing the speed drop, and in exactly the same proportion. By a careful study of conditions the initial assumption may be made quite accurately, though it is sometimes advisable to work out two or more assumed cases before making a final decision.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

714—Starting Two-Phase Induction Motors—A number of two-phase induction motors are connected through a four-pole double-throw switch to the secondaries of two starting transformers in such way that when the switch is in a starting position one-half of the secondary winding of each transformer is connected in series across each phase of the motors, the half winding of one transformer being made common to the two phases by means of a cross-connection joining the middle points of the two transformer windings. In the running position, the full secondary winding of each transformer is connected across a motor phase. The switch is thrown up for starting and, when the motor is speeded up, is quickly thrown over to the lower position. Please explain what happens in the process of starting with these connections. Would it injure the motors or transformers to operate with the switch in the starting position? A.B.

The voltage obtained on each phase of the motor when the switch is in the starting position is the resultant of two voltages, each equal to one-half of the full secondary voltage and having a phase relation of 90 degrees. By representing these voltage relations by means of vectors, it will be apparent that the starting voltage is equal to $\frac{1}{\sqrt{2}} \times$ running voltage. It should be noted that to start a number of motors from a single pair of transformers by means of a single switch, *i.e.*, with the motors all permanently connected in parallel, would require transformers of larger capacity and a larger switch than if a single pair of transformers and separate starting switches were used so as to start the motors one at a time. The burning of switch contacts would also be greater. Where step-down transformers are arranged on the secondary side so as to provide for running conditions as well as for a starting voltage, as in the present case, probably no harm would be done even if the motor were operated with the switch in the starting position, provided the load was light. However, a motor operating under load on reduced voltage is liable to take so heavy a current, due to the large slip, that overloading of both it and the transformers is apt to result; auto-transformers for use simply in starting induction motors are not ordinarily designed for continuous operation; and if so used are liable to develop trouble due to over-heating of the iron and consequent burning of the insulation. R.W.C.

715—Cylinder Lubrication in Small Gas Engines—Cylinder lubrication in small two-cycle gas engines is being accomplished successfully by dispensing with oil cups and mixing one pint of lubricating oil with each five gallons of gasoline. Could this system be used on four-cycle engines? Have any experiments been made to test it? A.G.

We do not know of any tests but think that, as the crank case of a four-cycle engine does not have the gasoline passing through it, the lower end of the cylinder and the bearings would need splash lubrication and if this splash lubrication is provided nothing else is needed A.T.K.

716—Ratings of Boilers—Please furnish names of several manufacturers of standard tubular and water tube boilers whose catalogues will give standard ratings of different sizes of boilers. K.W.A.

The most reliable makers do not seem to give sizes and horsepowers because conditions of draft, kind of fuel and kind of water

have their effect. Babcock and Wilcox, 85 Liberty St., New York, publish a book called "Steam" which gives much information along this line. A.T.K.

717—**Capacity of Steam Water-Works Pumps**—*a*—Please give formula for figuring the horse-power required to operate pumps of the plunger direct acting type as used in water-works service. *b*—What is the method of figuring the elevation head at which direct acting pumps can deliver water and do effective work. *c*—Are there any ready means of checking size of steam mains supplying pumps to see if they are of adequate size to supply necessary steam for efficient pump operation. K.W.A.

a—By the above we would understand pumps without flywheels. The indicated horse-power in the water cylinder is figured from the formula:—

$Hp = \frac{p \times l \times a \times n}{33\,000}$, where p is the suction in pounds per square inch + delivery pressure in pounds per sq. in., l is length of stroke in feet, a is area of plunger in sq. in., and n is number of double strokes per min. times the number of plungers. The indicated horse-power in the steam cylinders is greater than this by an amount equivalent to the friction. In small pumps the friction may be as great as the water horse-power so that the steam cylinder indicated horse-power will be twice the water indicated horse-power. In large pumps the friction may be less than ten percent.

b—If the ratio $\frac{\text{Steam indicated hp}}{\text{Water indicated hp}}$ is called R, then the head in feet against which the pump can work (suction + delivery heads) will equal 2.24 × Boiler Pressure × Area Steam Cyl. ÷ Area Plunger × R.

The steam consumption of small steam pumps is often as high as 120 pounds per steam indicated horse-power per hour. In large pumps it may be as low as 40 pounds. With compound pumps it may be as low as 25 pounds and with flywheel pumps it will go as low as 20 pounds non-condensing and 12 pounds condensing. *c*—Each pound of steam at 125 pounds pressure occupies 3.2 cubic feet. If the velocity of the steam in long lines is not over 100 feet per sec. and in short lines is not over 150 feet per sec. there should be no difficulty in supplying the steam. A.T.K.

718—**Converter Operated as Synchronous Motor**—Referring to question 643, July 1911, covering "operation of single-phase rotary converter as a synchronous motor," please advise how the converter could be so operated when the direct-current brushes are lifted, as recommended in the answer. On a converter of this type separate field excitation would hardly be used, so where would exciting current be obtained with the brushes lifted? D.D.W.

It is of course assumed in the answer that a separate source of excitation is available. In fact, unless the field current were adjusted to a value corresponding to approximately 100 percent power-factor the operation of the converter as a synchronous motor would be apt to be unsatisfactory, (of course depending upon the design) if it were attempted to use the direct-current side as a source of exciting current, because the variation of armature reaction with changes in load would tend to cause decided fluctuations of direct-current voltage. F.D.N.

719—**Static Condenser for Power-Factor Correction**—Why are not condensers made up with plates used in raising power-factor instead of synchronous motors. For example, voltage 440; power-factor, 75 percent, kw 750; required to raise power-factor to 80 percent or better. Why could not a condenser made of plates be used and do the work as well as a synchronous motor? F.H.W.

Undoubtedly a plate condenser can be made to raise the power-factor of a 750 kw circuit from 75 to 80 percent with a voltage of 440. Such a piece of apparatus, however, would not work as well as a synchronous condenser, for

three reasons; first, the cost would be several times that of the synchronous machine; second, the space required would be enormous, probably something in the order of 100 feet square and several feet high; third, particularly with the higher voltages, the I_2R and leakage currents would involve losses greater than for the rotating type. Some work has been done, in this country and abroad, on condensers of the electrolytic type, but considerable difficulty has been experienced with finding an electrolyte to produce the proper polarization or valve action, so that at present there is nothing commercially practicable in this direction. N.S.

720 — Synchronous vs. Induction Motors for Mine Air Compressors—In a large mining plant there are four motor-driven air compressors, all running in one locality and each of about 800 hp capacity. The frequency of the line is about 50 cycles. Two of the sets are driven by synchronous motors at 107 r.p.m.; the other two by induction motors at 104 r.p.m. I understand the reason all four machines were not driven by synchronous motors was that risk of hunting was feared, since the mechanical characteristics are identical. Please explain this. Are such precautions necessary? C.B.D.

If frequent starting of the compressors is necessary, induction motors are preferable, but if machines are started only once or twice a day, synchronous motors would be suitable. If an unloading device is used during the starting of compressors, either a self-starting synchronous motor or a synchronous motor with an auxiliary starting motor could be used. The self-starting synchronous motor is capable of exerting a starting torque of approximately 30 percent and pulling into synchronism with a torque of approximately 15 percent of the normal rated load. If a self-starting machine is used, the starting current may be twice the normal full-load current. If a starting motor is used, the starting current will not exceed the full-load current. Provided the fly-wheel of the compressor is properly designed, so as to avoid resonance troubles there is no danger of the synchronous machine hunting if the line drop is not excessive or there is no great variation in the frequency. Using induction motors for half the number of compressors would not avoid the danger of the synchronous machines falling out of step if it should happen that the natural period of oscillation of the motors coincides with the impulses of the compressor, as one machine would drop out of step just as easily as four. The induction motor however tends to eliminate hunting due to irregularities in the wave form or frequency, and very often a combination of induction and synchronous motors will work successfully when the latter type alone would not be operative. In the case of modern installations, where the frequency and wave form are regular and the line drop not excessive, synchronous motors alone are used quite successfully. The main disadvantage of the induction motor when running at slow speeds is the low power-factor. The efficiency will also be lower than with corresponding synchronous machines. On the other hand synchronous motors would require a separate exciting plant. They can be run at unity power-factor or at a leading power-factor to compensate for other inductive loads on the line. W.S.

721—Importance of Skin Effect—Is the skin effect in, for example, No. 4/0 single conductor stranded cable and larger an appreciable quantity, i.e., does its effect warrant using nothing larger than No. 4/0 at 2200 volts, or 240 volts, on the 60 cycle circuit? J.C.B.

The skin effect is not appreciable unless of a cross-section much larger than the size mentioned. For example, it may be an appreciable factor in limiting the carrying capacity of large bus-bars on switchboards with the higher commercial frequencies, such as 60 cycles, and must be given consideration in the design of large capacity power transformers for electric furnace work and the like in which relatively low secondary voltage is required, with correspondingly large secondary cur-

rents. In such apparatus the cross-section of the secondary conductors is apt to be such that special attention must be given to their relative position in order to minimize skin effect.

722—Method of Inspection of Electric Car Compressors—*a*—Please advise to what extent air compressors on street railway cars can be inspected from the pit without being removed from the car. *b*—What is the usual procedure in repairing a check valve which does not seat properly and therefore tends to keep the compressor constantly working? *c*—How often is the packing in brake cylinders usually renewed. If there are any books in print covering the subject of "Air Brake Equipment" I would like to learn about them. G.S.W.

a—The design of suspension cradle is such as to afford ready access to bolts and parts of the compressor requiring attention while in position under the car. The inspection includes condition of commutator and brushes, cleanness of motor, quantity and quality of oil in crank case, tightness of oil joints, wear in connecting-rod bearings, condition of strainer and condition of valves. *b*—Trouble from inlet and discharge valves is generally due to their being held off their seat either by burs, carbonized oil or other foreign substances. To remedy this, remove cap nut from cylinder head, take out valve and clean valve and guide of all carbonized oil or burs. *c*—It is almost impossible to say what the life of packing leather will be as this will vary under different railway and climate conditions. Our general recommendations for testing packing leathers for leakage would be to test at regular *three month* intervals by charging brake cylinder to 50 lbs. pressure and noting drop in pressure per minute. Leakage should not exceed five lbs. per minute. Should this rate be exceeded, brake cylinder should be dismantled, and packing leather and cylinder re-lubricated. Should cylinder again fail to pass this test, packing leather should be renewed. For articles on the subject of "Air Brake Equipments," refer to The Eight-Year Topical Index of the JOURNAL. Instruction books and other descriptive literature may be obtained on application to various makers of air brake apparatus. S.W.D.

723—Use of Clock on Switchboard—Would it affect a common spring clock to place it on the panel of a 2 200 volt switchboard. A potential transformer for the instruments is on the back of the panel. Would the clock be affected by the magnetism of the current? C.E.N.

A clock operated by a mainspring but having pendulum escapement would not be affected by a magnetic field. If a balance wheel escapement is used, however, the performance of the clock when within the influence of a strong field would be erratic; i.e., it would lose or gain time in an irregular manner. The clock would not be affected by a potential transformer nearby, as the transformer does not set up any appreciable field outside itself. A bus-bar carrying a heavy current close to a clock of the balance wheel escapement type might have some appreciable influence upon it. However, unless the bus-bar carried ten-thousand amperes or more, it could hardly be close enough to a clock mounted on the front of the panel to affect it. H.B.T.

CORRECTIONS

In the article on "The Operation of Mercury Rectifiers" in the February issue, page 148, the twelfth line from the bottom should read, "Bulbs are commonly guaranteed for 500 hours' use."

In the article on "Welfare Work of a Large Manufacturing Company," page 170, the first line of the sub title under the illustration should read, "Complete information regarding some 19 000 names is systematically"; also, on page 171, the third line should read, "are employed, and on test floors, with remedies to be used in case of."

PERSONALS

Mr. Henry W. Peck, assistant to the general manager of the Rochester Railway & Light Company, has been elected vice-president and general manager of the Schenectady Illuminating Company and the Mohawk Gas Company. Mr. Peck was formerly located in Pittsburgh in charge of switchboard work in the engineering department of the Westinghouse Electric & Mfg. Company.

Mr. Frank H. Taylor, formerly vice-president of the Westinghouse Electric & Mfg. Company, is on a short visit to the United States. Mr. Taylor is now director and general manager of the Lintoype & Machine Company, Ltd., with offices at 188 Fleet street, London, England.

Mr. E. T. Penrose, general manager of the Penn Central Light & Power Company, of Altoona, Pa., and formerly of the Philadelphia office of the Westinghouse Electric & Mfg. Company, has resigned to accept the position of electrical engineer of the Pennsylvania Coal & Coke Company.

Mr. P. M. Lincoln was appointed the official representative of the American Institute of Electrical Engineers, to attend the celebration of the 125th anniversary of the University of Pittsburgh, held on February 27-29.

Mr. B. A. Behrend has been awarded the John Scott Medal by the Franklin Institute for his contributions to the advancement of the electrical industry.

Mr. George W. Rousa, who for several years was connected with the engineering department of the General Electric Company, specializing in arc lamp work, has recently become associated with the arc lamp division of the sales department of the Westinghouse Electric & Mfg. Company.

Mr. William G. Housekeeper, who has been for some time engineer in charge of mercury arc rectifier work for the Westinghouse Lamp Company at Bloomfield, N. J., has resigned.

Mr. H. L. Dreyfus, of the railway and lighting department of the Westinghouse Electric & Mfg. Company at East Pittsburgh, has recently been transferred to the New Orleans district office.

Mr. V. W. Shear, of the railway and lighting department of the Westinghouse Electric & Mfg. Company, at East Pittsburg, has resigned to accept the position of electrical engineer of the Northern Ohio Traction & Light Company, with headquarters at Akron, Ohio.

Mrs. A. A. Rogers, formerly manager of the Denver office of The Westinghouse Machine Company, and later sales manager of its Chicago office, has severed his connection with the company to accept the position of general manager of the Portales Irrigation Company, Portales, New Mexico.

Mr. E. D. Kilburn, of the Syracuse office of the Westinghouse Electric & Mfg. Company, has resigned to become manager of the commercial department of the Empire Gas & Electric Company of Auburn, Geneva and Seneca Falls, N. Y., with headquarters in Auburn.

Mr. Cadwallader Evans, Jr., superintendent of the H. W. Oliver power plant, Pittsburgh, Pa., has resigned to become superintendent of mines and plant of the Arcadia Coal Company, Picton, Nova Scotia.

Mr. R. A. Millar, formerly connected with the New York office of The Westinghouse Machine Company, and located at Rochester, N. Y., has been made manager of the Philadelphia office to succeed Mr. H. P. Childs, who resigned to go into business for himself.

Mr. W. W. Briggs, of the San Francisco office of the Westinghouse Electric & Mfg. Company, recently spent several days at the works at East Pittsburgh.

Mr. D. D. Faris, connected with the Chicago office of The Westinghouse Machine Company as salesman, has been located at No. 27 Woodward avenue, Detroit, Mich., to look after the selling work in that vicinity.

The editorial, in the January issue of the JOURNAL by Mr. Gano Dunn, president of the American Institute of Electrical Engineers, entitled "On the Method of Nominating and Electing Officers in the American Institute of Electrical Engineers" is re-printed in the *Proceedings of the American Institute of Electric Engineers* for February, 1912.

PERSONALS.

Mr. W. H. Weeks, manager of the Detroit office of the Westinghouse Electric & Mfg. Company, and Mr. John D. Noyes, district engineer of the same office, have resigned to take up consulting engineering work in partnership, with offices in the Scherer Bldg., Detroit, where they are equipped to make complete reports, specifications and estimates on electric light, power and railway plants, and power transmission systems; appraisals, reports on operating conditions, etc.

Mr. W. C. Paine, formerly of the transformer engineering department of the Westinghouse Electric & Mfg. Company at East Pittsburgh, is now connected with the engineering department of the Allegheny County Light Company, Pittsburgh.

Mr. N. G. Symonds, for several years located at Indianapolis, Ind., as sales representative of The Westinghouse Machine Company, has been appointed sales manager of the Chicago office to succeed Mr. V. A. Rogers, resigned.

Mr. J. R. McClain, who recently completed the engineering apprenticeship course with the Westinghouse Electric & Mfg. Company, at East Pittsburg, has recently taken up work with the Rochester Railway & Light Company.

Mr. George R. Wood, consulting electrical engineer, of Pittsburgh, Pa., has accepted a position in the electrical department of the Berwin-White Coal Mining Company, Philadelphia, Pa.

Mr. J. E. King has given up his position in the industrial and power sales department of the Westinghouse Electric & Mfg. Company to become associated with the Nevada-California Power Company with headquarters at Goldfield, Nevada.

At a meeting on the morning of February 15th attended by Mr. V. R. Lansingh, president of the Illuminating Engineering Society, Mr. P. E. Millar, general secretary, and Mr. Norman Macbeth and Mr. G. H. Stickney, of the New York Section, the formation of a Pittsburgh Section of the Illuminating Engineering Society was ratified by the general council of the society. On the evening of the same day, at a dinner in the Fort Pitt hotel, the Pittsburgh Section was formally organized. The dinner was attended by about seventy men from Pittsburgh and vicinity, as well as by visitors from New York. Talks were given by a number of men interested in the promotion of the new Section. Temporary officers were elected as follows: Prof. H. S. Hower, of the Carnegie Technical Schools, chairman; Mr. H. S. Evans, vice-president; Mr. C. J. Mundo, secretary. The board of managers is composed of Mr. C. E. Clewell, Mr. W. Edgar Reed, Mr. E. R. Roberts, Mr. W. M. Skiff and Mr. P. S. Stewart. Delegates from Cleveland and Newark, Ohio, were present and pledged support to the newly formed Section.

The annual meeting of the American Society for Testing Materials is to be held in New York City on March 28-29. This meeting is held this early in the year on account of the meeting in this country in September of the International Association for Testing Materials.

The Wheeler Condenser and Engineering Company, of Carteret, N. J., have recently issued a very instructive and valuable booklet of "Steam Tables for Condenser Work." The ordinary steam tables were not designed for use with high vacua such as are encountered in turbine work. The presentation of complete tables for vacua as low as 29.5 in., along with discussion on methods of measurements and corrections to be made, makes this publication a valuable one for steam users. Copies will be sent on request to engineers using or proposing to use, condensing apparatus.

The Vixen Tool Company, of 5001 Lancaster avenue, Philadelphia, Pa. have gotten out a new catalogue of Vixen Rail Planers. This rail planer is a portable device for planing down rail corrugations, raised joints, etc. Copies of this catalogue will be sent on request.

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A few of the articles in Volume VIII for 1911 are given below:—

"Notes on Factory Power Costs"
"The Steam Turbine for Future Work"
"Fifteen-Hundred Volt Railway Equipments"
"The Incandescent Lamp in Use"
"The Effect of Starting Currents on Power Circuits"
"Grouping of Current Transformers"
"Factory Lighting Problems"
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THE REMINGTON TYPE BAR

"The life of the typewriter is the type bar." These are the words of Mr. W. K. Jenne, who from the beginning and for thirty-odd years thereafter superintended the manufacture of the Remington and is known everywhere as "The Father of the Writing Machine." To his skill and inventive genius the present high development of the writing machine is largely due, and he is pre-eminently qualified to speak with authority upon the mechanics of the subject. Well may Mr. Jenne limit the life of a typewriter to the life of its type bars. On the type bar comes the heaviest strain. On the type bar bearing fall's the roughest wear. If the type bars are weak, the whole machine must of necessity be weak and short lived. Therefore, we cannot escape the conclusion that no typewriter can possibly be stronger than its type bars. Also, that the machine with the strongest type bars is bound to be the longest lived typewriter.

The Remington is known as the longest lived and most durable of all typewriters. Perhaps the best evidence of Remington strength is the Remington's reputation as the best machine for heavy manifolding. Manifolding demands strength, surpassing strength, and the machine which is the best manifolder is bound to be the strongest writing machine.

Remington type bars are drop forged and are hung on broad pivot bearings. The manufacture of the Remington type bar and its assembling in the bearings involves thirty-three distinct processes. These two sentences tell in a few words the whole story of Remington type bar supremacy.

"Drop forged" type bars! If that term "drop forged" does not convey a distinct meaning to you, please consider how other type bars are made. They are simply stamped from sheet metal, on the same principle that grandmother used to cut out biscuits with the cover of the baking powder can. Drop forging does not mean cutting; it means hammering. It is a method which literally hammers strength and temper into the bar in the process of the making.

The drop forged type bar is, of course, an old Remington feature. But it is not an old feature on a Visible Typewriter. The Visible Remington Models have the historic drop forged type bars. In other words, they are more than visible writers; they are Remingtons.

ANNUAL CONVENTION, ELECTRICAL DEPARTMENT MANAGERS AND SALESMEN, H. W. JOHNS-MANVILLE CO.

On February 5th, there assembled in the new Manville building, Madison avenue and Forty-first street, New York, over one hundred men who had arrived from all parts of the United States and Canada to attend the annual convention which the H. W. Johns-Manville Company hold for their electrical department managers and salesmen.

Mr. J. W. Perry, general electrical manager, called the convention to order and briefly outlined the purposes of the meeting. The following papers were presented: "Modern Illumination", by W. H. Spencer, illuminating engineer of I. P. Frink Company, the sole selling agency of which has recently been acquired by the H. W. Johns-Manville Co.; "J-M Linolite", by W. S. Kilmer, the company's illuminating engineer; "J-M Linolite Lamps," by Dr. J. F. Meyer; "Westinghouse Lamps", by Norman Macbeth and B. F. Fisher; all three of these men being connected with the Westinghouse Lamp Co.; "J-M Transite Asbestos Wood", by S. A. Williams, W. D. Ligon, S. P. Russell and F. C. Reilly; "J-M Fibre Conduit", by W. D. Ligon and W. R. Seigle; "Overhead Line Material", by C. W. Schultz and W. D. Ligon; "Electrobestos Insulation and Dielectric Cements", by J. R. McLain; "Friction Tapes and Splicing Compound", by J. W. Perry and H. M. Frantz; "J-M Electrotherms and Special Heating Devices", by J. R. McLain; "J-M Air Brake Cylinder Packing Expander Rings", by George Christensen; "J-M Dry Batteries", by E. Whitmore; "Lightning Arresters, Trolley Catchers and Retrievers", by W. R. Garton; "Asbestos Products for Electrical Power Plants", by L. R. Hoff.

Those attending the convention also went to Hartford, Conn., where meetings were held at the factory of the Johns-Pratt Company, for which the H. W. Johns-Manville Company are sole selling agents. Papers were read on "Noark Enclosed Fuses", by R. C. Coles; "Noark Service, Fuse and Subway Boxes", by D. C. Hooker; "Insulating Materials and Overhead Line Material", by Messrs. A. G. Newton, R. B. Lattin and C. W. Schultz.

The convention closed with a banquet at the Hartford Club to the representatives present, by the Johns-Pratt Company.

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NEW BOOKS

"Elementary Lectures on Electric Discharges, Waves and Impulses, and other Transients"—Charles Proteus Steinmetz. 349 pages. 64 illustrations. Published by McGraw-Hill Book Company, New York City. Price, $3.00.

This latest addition to the group of books by this author may be considered as an introduction to the study of his previous work, "Theory and Calculation of Transient Electric Phenomena," or as the author indicates, "Its translation from mathematics into English." Numerous oscillographs taken on various commercial electric circuits are shown in addition to theoretical curves to illustrate transient conditions. The book is divided into ten lectures, as it is based on a series of lectures given at Union College; among the headings are,—single energy transients on direct and alternating-current circuits, double energy transients, line oscillations, traveling waves, oscillations of the compound circuit and the inductance and capacity of round parallel conductors.

"Good Engineering Literature"—What to Read and How to Write, with Suggestive Information on Allied Topics. By Harwood Frost. 422 pages, cloth 5 by 7½ inches. Price $3.00. Published by the Chicago Book Company. For sale by THE ELECTRIC JOURNAL.

The faculty of forceful writing is innate with but a few, whence the majority of authors must acquire through study and application the necessary ability to formulate a discussion of a definite subject in an effective and instructive manner. There is an apparent need in the engineering world for improvement in technical writing. While the essential elements in the composition of scientific treatises, either of academic or practical nature, has been presented before, Mr. Frost's work constitutes a most useful dissertation on the construction of engineering literature. The author's training as an engineer and his experience with a leading engineering journal and particularly in its book department affords him the intrinsic qualifications to guide and aid in developing facility and dexterity as regards technical presentation. In general, the author denotes the required fundamentals in grammar and rhetoric, the best method to approach an extensive engineering discussion or treatise, the features in the make-up and publication of books, copyrights, etc., together with the proper selection and collection of engineering literature. It is almost needless to impress the value of Mr. Frost's contribution, for use in both construction and choice of technical material. The book is published in inexpensive form, establishing a moderate cost and, therefore, expanding its availability. E. D. D.

"Principles of Industrial Engineering"—Charles Buxton Going. 165 pages. 6 by 9 inches. Published by McGraw-Hill Book Company, New York City. Price $2.00.

The theme which Mr. Going has taken up applies almost entirely to works management and factories for general manufacturing. The book is based on a series of lectures given by the author before the mechanical engineering students of Columbia University. The author is well acquainted with the essential elements of this important subject and, moreover, the striking feature of this book is its extraordinary clearness, which leads the reader to a quick conception of the fundamentals underlying sucessful industries. Well-appointed chapters compensate for the abridgement, which give a good foundation for the station engineer and manager. Frequent discussions of the work of the prominent exponents of efficiency systems are included. The author reviews the development of industrial systems; how organizations are established and governed, and gives an extended analysis of the elements of costs, expense burden, labor and material, and the various features which affect them. E. D. D.

"Cooper Handbook"—Horace J. Stevens. Tenth edition. 1902 pages (5½x8½ inches). For sale by THE ELECTRIC JOURNAL, Pittsburgh, Pa. Price, $5.00.

The Cooper Handbook, which is considered a standard authority on the subject of copper and copper mines for the entire globe, describes 8130 copper mines and copper mining companies, in all parts of the world, this being the largest number of titles ever listed by any work on mining. The descriptions range from two or three lines, in the case of dead companies, wherein reference is made to detailed descriptions in past volumes at the period of their activity, up to twenty-one pages in the case of the Anaconda Mine. The miscellaneous chapters of the book, twenty-four in number, treat the subject of copper from all possible viewpoints, there being chapters on the history, chemistry, mineralogy, metallurgy, brands and brades, alloys and substitutes for copper, with a copious glossary.

THE
ELECTRIC JOURNAL

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Steam Turbine Development

The article in this issue of the JOURNAL, on the subject of "New Developments in Steam Turbine Engineering," treats briefly of the historical development of the turbine, showing how from year to year larger sizes and finer performances have been reached. There is also shown the broadened range of applications under a great variety of operating conditions, capacities and speeds. Turbines are discussed which operate with high pressure steam, low pressure steam and also in conjunction with heating systems.

The development of the steam turbine, in all its various forms, has probably been more rapid than that of any other prime mover in the history of engineering. This, really, is not extraordinary, and has been due to the condition of the mechanical arts, as developed by others building reciprocating engines. The various developments in steam turbine work have branched into such a variety of applications, that they can be treated only too briefly in any single article attempting to cover the whole ground.

The real economies of power plant operation, resulting from the application of modern steam turbines, are appreciated by but few people, inasmuch as they take cognizance only of the fuel consumption of the plant. It is true that steam consumptions have been reduced from, say, 18 to 20 pounds per kilowatt-hour down to from 13.5 to 14.5 pounds in more or less every-day large installations, which is truly a substantial gain. But a greater gain comes from the reduced first cost of power plants, viz., a reduction from about $120 per kilowatt to approximately $60, so that when making proper allowances for this in the fixed charges against the plant, it is equivalent to a total reduction in the operating expense of from thirty to sixty percent, including reduced power house labor expense.

This article is fairly replete with sectional drawings, showing the latest types of turbines, which add greatly to its interest.

FRANCIS HODGKINSON

Weatherproof Sub-station Apparatus

High voltages are necessary for the economical transmission of large amounts of power for considerable distances. The higher the voltage, however, the greater is the cost of the transforming, switching and protective equipment. Secondary systems of distribution are not practicable in a great many cases, owing to the distances separating the various loads. Anything, therefore, which tends to lessen the cost of a sub-station becomes an added reason for the installation of a sub-station, which might otherwise have been commercially impracticable. The development of transformers for out-door service for capacities greater and for voltages higher than usually found in distribution work, and the development of outdoor switching and protective equipment has eliminated the one item of greatest cost in the equipment of any sub-station; that is, the cost of the building proper. As this item of building is nearly as much for a small installation as for a large one, for a given voltage, it follows that the small and moderate capacity installations can show the greatest proportionate saving by the use of the outdoor type apparatus.

From a small beginning a few years ago, there is now a well-recognized demand for transformers of the type described in the article on "Outdoor Type Transformers" in this issue of the JOURNAL. The growth has been steady, though not extremely rapid. A reason for the rather slow increase in the use of outdoor type transformers has been a general disinclination to use anything until its worth has been proven. The installations and the very successful results obtained during the last few years have proven that the outdoor transformer is no longer an experiment.

The prime requisite of the outdoor transformer is simplicity of design and a mechanical ruggedness which will stand up under all service conditions. The present article is particularly opportune, for at this season of the year the power transmission companies are engaged in outdoor construction work and extensions of their systems. All indications go to show that the next few years will see a wonderful growth in installations of the character described by Mr. Lawson.

H. H. RUDD

Power Plant Costs

Messrs. Lyford and Stovel have done a notable service to the engineering fraternity in presenting the data contained in the paper that they recently read before the Engineers' Society of Western Pennsylvania, extracts from which appear in this issue of the JOURNAL. Those who have studied the matter of power plant costs know the difficulties in the way of making any generalization in this matter. Therefore, when two such experienced and conservative engineeers as the authors of this paper consent to delve into their vast store of experience and crystalize it into the data they have given, the engineering fraternity has cause to be appreciative.

The final result arrived at by these authors is that a power plant, of the nature described, will cost somewhere between a minimum of approximately $40 per kilowatt and a maximum of approximately $80 per kilowatt. Between these limits, the cost depends upon local conditions, character of load factor, cost of fuel and some other features that may vary over a considerable range. Judgment on the individual case must therefore fix the exact cost within the limits indicated by the authors. However, this judgment on the individual case is made rather easy of application by placing limits on each of the items that go to make up a complete power plant.

In reviewing this paper, one is impressed by the relatively low cost per kilowatt that is finally arrived at. Sixty dollars per kilowatt is an approximate average between the maximum and minimum limits given by the authors. Time was—and not many years ago—when the average cost of power plants was perhaps double this figure. One of the important reasons for this large decrease in cost is the fact that the steam turbine has come into general use within the last few years. This modification of power plant practice has brought with it very much higher speeds and a consequent use of materials at a point where the output per pound is much higher than was possible with the old reciprocating units. To be sure, the cost per pound has gone up, but the output per pound has gone up even more rapidly and a considerable net saving in cost per kilowatt has resulted.

The Significance of Standardization

A complete record of the work that has been done during the last decade by governments, national and international engineering societies, and individual manufacturers, in the direction of standardization would be such as to touch upon practically every phase of the world's industrial and commercial activities—so far reaching is the influence of this important element in our every-day life. In fact, it is surprising to find to what extent those who follow a well-ordered existence are given to standardization of thought and action.

That the establishing of standards is entirely consistent with progress, and not only need not interfere with healthy development but may be conducive to increased effectiveness, provided they are adhered to only to the point of reasonable practicality, is being demonstrated by hundreds, if not thousands, of industrial and manufacturing concerns whose present efficient methods of production —which are necessary to meet competition—are based primarily upon the economic principles of standardization. In the development of new apparatus it is repeatedly found possible to save valuable time by specifying such standard detail parts as have proven themselves satisfactory in service. Not only are the advantages of such design work felt in practically every stage of the manufacture of the apparatus, but incidentally the more inexperienced designer, for example, is in a certain measure given the benefit of the experience of many. A great deal of development work may thus be based on certain pre-determined data, or empirical conditions which are taken for granted, and attention given to the primary features of the work. On the other hand, too extended an application of this principle may lead to limitations of design. Thus, when a useful invention is brought forth as a result of research which reverted to some commonly disregarded fundamental principle we are often led to exclaim, "How simple; why has no one thought of that before!"

It would nevertheless be difficult to gauge fully the benefits, both to producer and user, of such time-saving information when it is so recorded as to be conveniently accessible. The value of the steel manufacturer's handbook of standard sections, for example, with its quantity of supplementary information and useful formulae, is very obvious. Corresponding information of like value to those concerned is issued in handbook form by electric cable and wire

manufacturers. Again, the benefits accruing through standardization of wiring methods and details, as covered by the National Electrical Code of the National Board of Fire Underwriters and the similar instruments in effect in other countries, in the matter of safeguarding property and preventing accidents, is probably too little realized. The handbooks of the mechanical engineer, the electrical engineer, the civil engineer, the architect, the mining engineer, the metallurgist and the chemist, all in turn represent the results of untold effort in the collection of standard technical information of common utility. Miscellaneous handbooks are to be found to-day covering practically every industry of importance; not to mention the publications compiled and issued by the United States Bureau of Standards.

The brief historical outline of what has thus far been accomplished in the matter of standardization through organized action, which is given in the article on "Standardization" by Mr. H. F. Chadwick, in this issue of the JOURNAL, is of itself a remarkable and significant record. In a continuation of this article Mr. Chadwick will discuss the standard methods which have been evolved in a practical way by a large manufacturing company in the application of the general principles set forth in his present discussion. As in the case of steel manufacturers and the cable companies, the necessity of compiling some form of standard book to contain experimental and empirical information of a general nature, supplemented by data pertaining specifically to the company's own products and shop methods, became apparent. The description of some typical problems which were involved in compiling this loose-leaf book—at present a collection of considerably more than three hundred pages; the way in which the problems were solved, and the results derived through their successful solution, form an intensely interesting and instructive story which is valuable to have on record because of the applicability of the methods, in a general way, to many other industries.

A notable illustration of the importance and of the convenience and utility of this standard book and the engineering and shop methods for which it stands, is found in the article by Mr. C. B. Auel, in the JOURNAL for October, 1911, in which he describes some of the steps in the manufacture of a modern railway motor. By the use of pin gauges machining is done on motor parts in large quantities and accurately checked to minimum allowances of from

two thousandths to five ten-thousandths inch, as the case may require. The necessary data for reference in determining the allowable arc through which the pin gauge may swing in checking the diameter of any given bore is covered in the standard book. This is but one type of specific gauging problem for which complete records must be on file; but the case in question is illustrative of what is commonly being accomplished by present-day engineering and shop methods.

One of the limitations placed upon the manufacturer by lack of standardization, as enumerated in the present article, is that of his being unable to carry stock of finished product or interchangeable repair parts. This, of course, is intimately related to cost of production, an economic factor eventually of as great importance to the consumer as to the producer, for it is the consumer who finally pays for overhead costs, such as for extra development work, wasted material, expensive tools or the cost of setting up special work. Hence with a properly developed system of standardization of both design and manufacture, products are made most economically in quantities. Primarily, of course, aside from the above question of cost, the idea in maintaining stock of apparatus is to facilitate delivery. Concrete examples of modern methods of production are found in the systems followed by various prominent industrial corporations for the buying of raw material and the manufacture of such apparatus or parts of apparatus as can thus be made best in quantities, which serve to indicate the close relation between standardization and economy of production. An ideal method of operation, from the standpoint of monetary investment, is so to regulate the ordering of materials to be made up into stock that, allowing for the time required for manufacture in the shop, a new stock will begin to be available when the last of the old stock is shipped; that is, new stock will be ordered when a certain fixed minimum available stock is reached. The quantity of raw material ordered must be determined, however, by many practical considerations. For example, the common advantage of buying in large quantities, and producing in quantities certain items in finished or semi-finished form, particularly where they require costly setting up of machines for their manufacture, must be kept in view. Market prices may also influence ordering of materials, and again it may be necessary to allow for delays in shipment of raw material supplies. Furthermore, in the shop, many factors must be weighed in determining the best engineering and manufacturing policy. At best, a

very large number of different kinds and sizes of detail parts must be made when a large variety of apparatus is manufactured, and therefore the farther standardizing of detail parts can be carried the less complicated will be the problems of design, production, and carrying of stock. Where, for instance, ten different machines have certain detail parts which can just as well be made alike as otherwise both in dimensions and material and, say, five hundred pieces of apparatus of each type are on order, the detail parts in question, if standardized, can be made in lots of five thousand, with perhaps a single setting up of a complicated automatic machine. If in turn the apparatus as a whole is of some established standard form, the principle may find even broader application in effecting economic production, especially where it is found desirable to keep a considerable stock of finished or semi-finished parts. That these considerations find general application in industrial work will be evident from a study of the detail catalogues issued by any of the large manufacturers of the country.

E. R. SPENCER

New Associate Editor

Since its inception, the JOURNAL has been fortunate in having associated with it a number of prominent engineers who have acted in an advisory capacity as associate editors. It is now able to announce a further addition to its staff in the person of Mr. B. A. Behrend, the well-known consulting engineer, of Boston. Mr. Behrend's long experience as assistant chief engineer of the Oerlikon Company, chief engineer of the Bullock Electric Mfg. Company of Cincinnati, chief electrical engineer and consulting engineer of the Allis-Chalmers Company of Milwaukee and the Allis-Chalmers-Bullock Company of Canada, as advisory engineer of the Westinghouse Electric & Mfg. Company of Pittsburgh, and his further experience in private consulting practice, as well as the fact that he is himself a technical writer of note, will be of great value to the JOURNAL, which will now be in a position to profit by his advice and counsel.

NEW DEVELOPMENTS IN STEAM TURBINE ENGINEERING

EDWIN D. DREYFUS

THE first mile stone of turbine progress was reached when Parsons introduced his unique turbine in 1884, which time witnessed the transition of the steam turbine from the realm of virtual mysticism, as these motors in their primitive form probably impressed the people of the earlier days, into apparatus of commercial utility. Advance was naturally slow, during the early period of development, but notable headway was gained in the 10 to 15 years following its introduction. The most prominent factor in preventing a more general use of the turbine was the lack of machinery which could utilize the power developed in a practical way. The turbine, having an inherently high speed, made the provision of a driven machine of corresponding speed necessary, or else connection through reducing gears, and inasmuch as these were not available in the infancy of the industry, turbine progress has therefore been more or less closely related with the complementary electrical equipment—chiefly of the alternating-current type.

The first generator which was driven by a turbine, was of the historic bipolar design, operating at a normal speed of 18 000 r.p.m. and developing a maximum output of six electrical horse-power. From this modest beginning the turbine was energetically pushed, and by 1889 turbine units aggregating 5 000 kilowatts were installed and operating, and by 1894 the 10 000 kilowatt mark had been reached. This period witnessed not only the initial application of the turbine to marine work, but also marked a beginning of the broad highway of turbine progress leading down to the present day which claims an aggregate turbine capacity of 25 000 000 horse-power in actual service.

The developments have been so far reaching during the past few years, that many new mile stones have been rapidly passed. Thus, for instance, the range of turbine capacities has been extended from 1 to 20 000 kilowatts and above; the low-pressure turbine, the automatic bleeder turbine and the improved non-condensing turbine have been accorded wide application in central station work; and in auxiliary service such as excitation, boiler feeding and condensing equipment, the small turbine is filling a long-felt need. The practical development of the reduction gear for high powers has brought the turbine into the high duty water

pumping field, and has provided for the application of large high speed turbines to direct-current generation, and likewise to non-reversing rolling mill drive. Thus it may properly be said that the turbine has invaded practically every class of power application with the possible exception of those cases requiring reversing operation, such as in hoisting and blooming mill work.

As a means of reviewing turbine development, Table I may prove interesting.

TABLE I—PERFORMANCE OF PARSONS TURBO-GENERATORS AT DIFFERENT EPOCHS*

Date	Power Kw.	Steam per Kw-hr.	Vacuum 30" Bar.	Superheat Deg. F.	Steam Pres. lb. per sq. in.
1885	4	200	0	0	60
1888	75	50	0	0	100
1892	100	27	27	50	100
1900	1250	18.22	28.4	125	130
1902	3000	14.74	27	235	138
1907-10	5000	13.2	28.8	120	200

From this it will be seen that the turbine came up to the best reciprocating engine performance in a comparatively short time, and to-day excels in all important sizes.

RANGES IN COMMERCIAL SIZES

Probably one of the most notable features of turbine progress has been the remarkably short space of time in which its design has become feasible for both very small and very large powers. A few years ago the concentration of 50 000 horse-power in a single machine was not considered seriously even by those who are customarily accredited as visionary. Although at the present moment, no turbine has reached these stupendous proportions, we are, however, to-day observing the building of units of 30 000 horse-power and the next step to the large size named is now readily surmountable. One may fully grasp the significance of this advance, when it is considered that a 30 000 horse-power unit will displace four of the largest reciprocating engines built, and moreover occupy but 25 percent of the floor space. It is at once apparent that there is a large measure of economy realized both in investment and running expense. With increasing size of turbines there is a continual improvement in economy, all conditions being favorable.

The most important factor in large turbines then, is the question of mechanical design. There can be no doubt that rigorous

*From A. Richardson, "The Evolution of the Parsons Steam Turbine."

demand is made of the designer that the essential details be executed with every regard for operating loads and stresses. Several different types of large turbines are now available, but the preëminent fitness of any one will be gauged, of course, by its relative immunity from troubles of any moment. The drum type turbine has much to recommend it particularly for units of large power. A detail section of a turbine of this construction is presented in Fig. 1, and which, as proportioned, is capable of developing 20 000 kilowatts or 30 000 horse-power continuously. This represents the double-flow type, combining the impulse and reaction principles. Through the division of steam between the right and left hand elements, higher rotative speeds have been made possible with the reduction in diameter of the low-pressure rings. As a result substantial betterment in construction has been effected, and a decrease

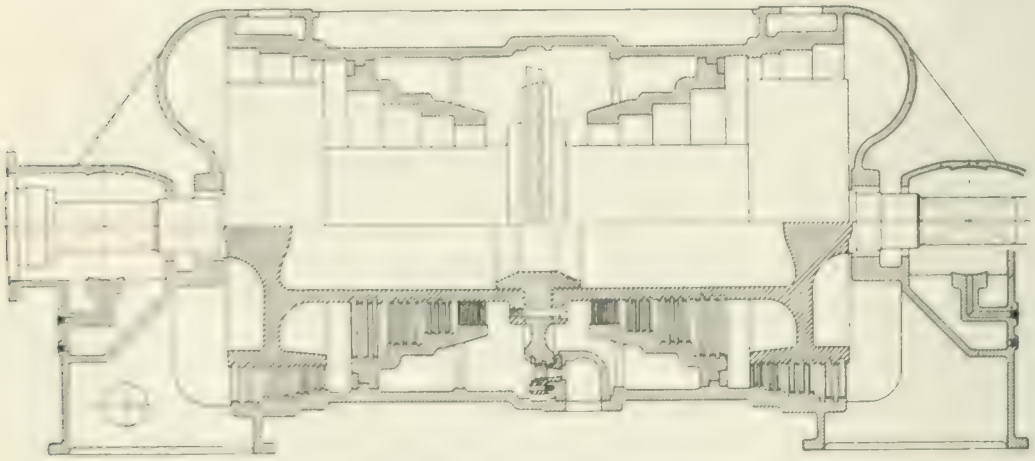


FIG. 1—SECTION THROUGH 20 000 KILOWATT STEAM TURBINE

in weight and dimensions, ensuring greater homogeneity of the entire structure. It will be noted that the unit is constituted entirely of drum and blade rings. Discs are not employed. Operation at 1 500 r.p.m. may appear somewhat startling at first when it is considered that some of the early designs of turbines adopted speeds of 750 r.p.m. for units of only 2 000 kilowatts capacity. Strange as it may seem, although the disc construction is capable of being worked at higher stresses than the drum type, the latter may be constructed with greater facility to comply with requirements of good steam economy and still possess the greater factor of safety. The steam consumption with moderate working conditions, (175 lbs. pres., 100 degrees supht. and 28 in. vac.) would at full load amount to about 13.5 lbs. per kw-hr.

When the very small turbines are considered the problem is of a different order in obtaining maximum simplicity with reason-

able efficiency. Such a turbine is comprised of a single wheel with one row of impulse blades. Double use of the velocity of the steam is effected through reversing chambers, which contributes toward higher efficiencies. Any practical requirement calling for even less power could be inexpensively provided for in a turbine of this type.*

Between such limits the variations in design are quite marked. Single disc wheel construction is retained until capacities of 300 kilowatts are reached. At this point, the steam volume becomes sufficient to use reaction blading of economical proportions. There is manifestly a definite relation of the leakage annulus or area over the tips of the blades to the blade lengths, which prohibit their use commercially in smaller sizes. On the other hand, the percentage leakage loss greatly diminishes with increase of size, and the economy is correspondingly improved.

Consequently there exists a large variation in construction depending upon both working conditions and capacities involved and the designs therefore take either the form of a simple impulse wheel, or the straight Parsons construction, or else some effective combination of the two. For moderate sizes, somewhat above and below 1 000 kilowatts, the straight Parsons type, works out most advantageously in regard to economy and mechanical design. In larger sizes, there is much gained from a structural standpoint through the use of the combined type, although the efficiency is not noticeably affected. The condition is practically the reverse in small units, where the construction requirements cease to be a factor while the efficiency may be improved by replacement of the very short blades in the high pressure section of a Parson turbine by an impulse wheel. As the character of the work varies different arrangements may be adopted, and these facts simply serve to illustrate that the turbine is no longer circumscribed by narrow limits, but admits of wide flexibility in its application. Many of the features here described will be observed in the accompanying detail views of turbines built for various purposes.

SPECIAL SERVICE

Under this classification, the implication is that special regard must be paid to proportioning of the turbine with reference to the nature of the steam supply as well as its speed and the output developed. It is here taken that the complete expansion of the steam

*This type is described in detail in the author's paper "Steam Turbines for Electric Stations of Moderate Size" in the JOURNAL for September, 1911.

from boiler pressure to the absolute vacuum maintained represents ordinary practice, and would therefore require only the regular designs already referred to. But there are sets of conditions which call for special designs and which typify some of the more prominent of recent developments in the steam turbine art, as briefly enumerated below:—

a—Utilizing low steam pressures, atmospheric or less.*

b—Operated strictly non-condensing, with or without back pressure.

c—Diverting part of the steam from the turbine for heating purposes, termed bleeding operation.

Low-pressure turbines have now become so well known that little mention of their advantages need be made here. It is possibly well, however, to reiterate the salient point that they profitably utilize the lowest practical exhaust pressures, where the reciprocating engine would receive no benefit, direct or indirect. One of the most convincing demonstrations of this quality of the turbine is the great many stations which formerly operated non-condensing piston engines on account of inadequate cooling water supply, which are being converted into condensing plants through the addition of low-pressure turbines and cooling towers. The engines alone would not have justified the cooling tower investment. Improvement is not only to be found in the existing non-condensing systems, but power plants formerly consisting of the most modern type of compound condensing reciprocating units have been able to realize a large betterment in economy by supplementing the engines with low-pressure turbines. A concrete example will forcibly attest the economic results attained.

An electric railway power station originally contained five 1 000 kilowatt Corliss compound condensing engines. A low-pressure turbine of 2 500 kw capacity was later installed. Concisely the improvement obtaining is:—

1—Plant capacity increased 50 percent, additional boilers unnecessary.

2—Reduction in station operating force, 15 percent.

3—Fuel saving 22 percent. The fuel is of 11 000 B.t.u. value, costing $1.40 per ton delivered and the saving is equivalent to a return of 48 percent on the investment, or, in other words, the new installation would pay for itself in two years time.

*Curiously the first steam engine operated altogether on low-pressure steam (atmospheric to condenser pressure) but this was due to the state of the mechanical art, high-pressure boilers not being available at that time.

Besides these items, there is economy effected in oil, supplies and repairs. Moreover, this addition was made at roughly one-half the cost that would have been necessary to install duplicate engines. A type of low-pressure turbine which is extensively used, also embodies the double-flow construction, and is very similar to Fig. 1, with the high-pressure part, however, removed.

That part of low-pressure turbine engineering which attracts the greatest attention, is the variety of the systems of governing which have been developed to secure satisfactory elasticity and efficiency over a wide range. These may be divided into approximately six classes, and which as given on previous occasions,* are as follows:—

a—Without governor, electrically controlled through synchronizing force of generators.

b—Governor control with auxiliary live steam admission.

c—Electrical tie between turbine and belt engines through synchronous motor.

d—Automatic by-passing of surplus low-pressure steam to condenser.

e—Use of a reserve high-pressure element.

f—Heat regenerators, accumulators and storage systems.

While heretofore the development of the low-pressure turbine has centered mainly about the governing mechanism, an important innovation in the mechanical design has been made in the construction of a convertible type as shown in Fig. 2. This is a single-flow reaction element with provision for the introduction of a high-pressure impulse wheel when operating conditions may demand it. Such a type would prove of great value in the case of abundant exhaust steam being available at first, but afterwards being seriously reduced by other changes about the plant, full advantages of the low-pressure feature may thereby be lost. By locating a high-pressure wheel as shown, the turbine may be operated economically either as a mixed pressure or independent high-pressure unit.

Much has already been said of the facility with which low-pressure turbines may be adapted to widely different requirements. There is another feature, in combining it with a given engine, worthy of special comment: viz., that the low-pressure turbine to be selected need not be confined to a fixed capacity. On the other hand, there is considerable latitude practicable in the selection

*"Various Phases of Low-Pressure Turbine Work," in the JOURNAL for May, 1911.

of the low-pressure turbine, thus making possible different overload capacities and light-load economies without greatly affecting the efficiency of the combined unit at rated output. With these advantages, the size of low-pressure turbine would then be influenced either entirely by present conditions or by future requirements as regards the combined normal capacity.

The points to be considered center primarily about the selection of the intermediate pressure between the engine and the turbine to carry normal capacity of the turbine. Obviously the higher this pressure is set, the smaller the low-pressure turbine frame for a given capacity. On the other hand, the lower the pressure taken for normal conditions, the larger the low-pressure turbine frame

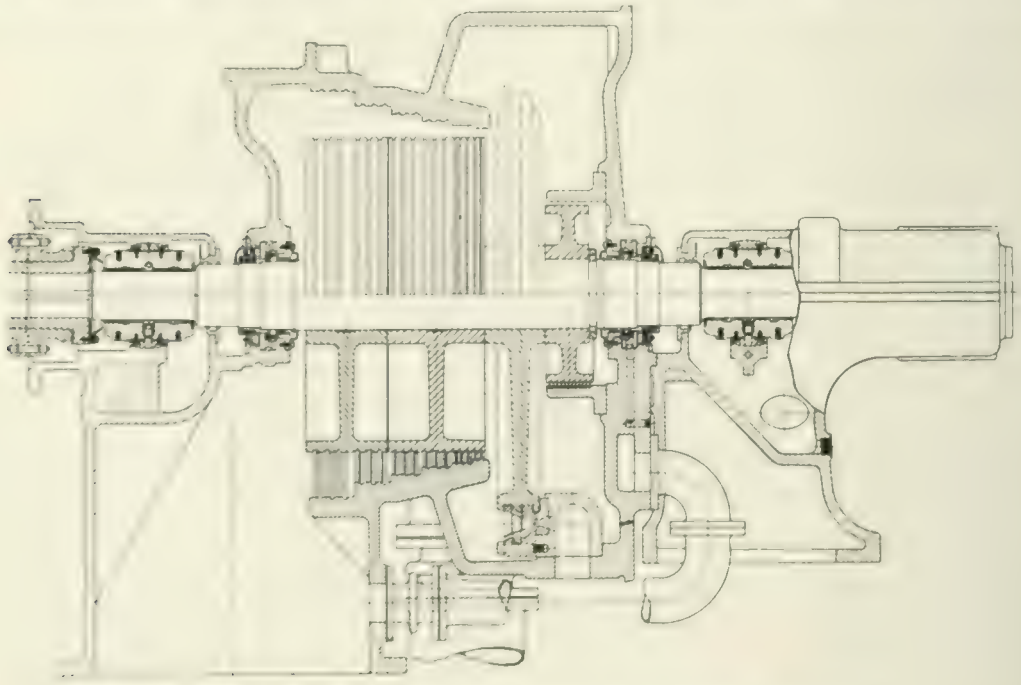


FIG. 2—CONVERTIBLE TYPE OF LOW-PRESSURE TURBINE

must be. Evidently in the first case of a high intermediate pressure, the output from the engine becomes materially reduced and maximum overloads, which may be carried, are likewise affected. This fact may be best appreciated from Fig. 3, showing the total water characteristics of the high-pressure engine when operated in connection with turbines of different sizes. As the back pressure on the engine is lowered, the turbine size must increase, which in addition to extending the point of maximum economy of the engine, also raises the capacity of the combined unit. The range in operating load should also be considered since, where larger turbines are operated at light loads, the economy may be inferior to that shown by the unit having the smaller low-pressure turbines.

This is due to the fact that light load losses, for fractional load operation of the combined unit, are greater for the larger than for the smaller turbine.

By working out a definite case it has been found that where the turbine size is increased as above, the gain in the engine, due to lowering the back pressure, slightly exceeds the loss in the turbine element following upon a decreased inlet pressure and fractional load operation. This is evident from Fig. 3, showing results that have been worked up for a 28 and 54 by 48 inch engine, operating with low-pressure turbines ranging from 500 to 2 000 kilowatts in capacity.

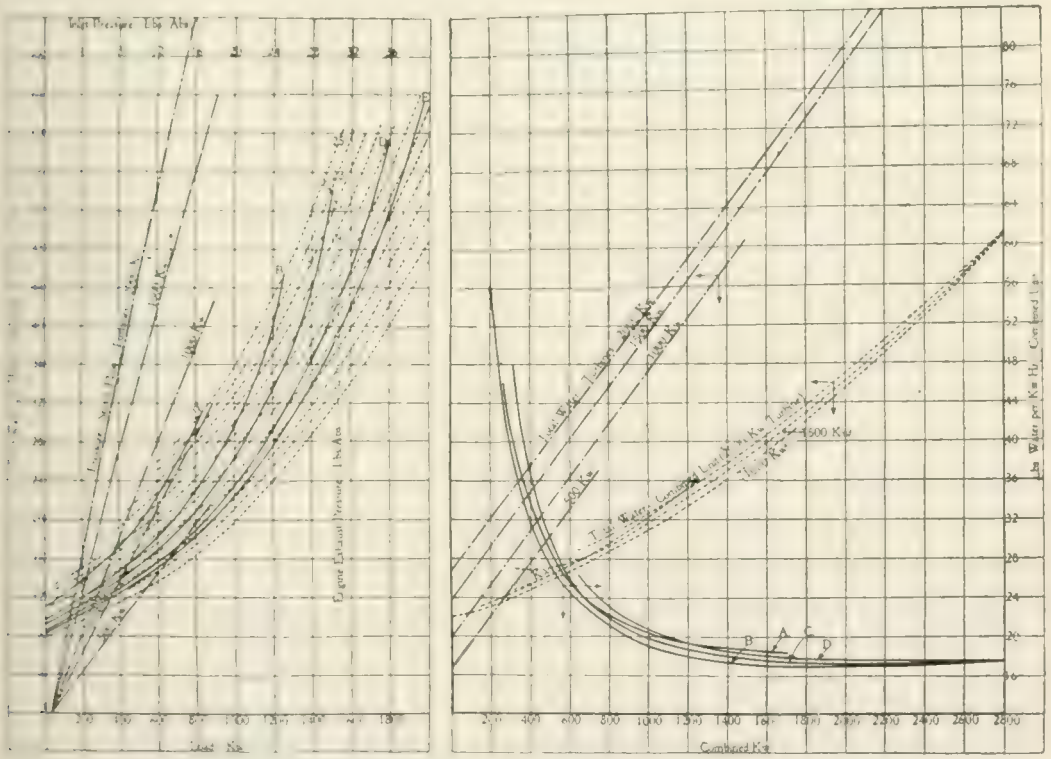


FIG. 3—COMBINED WATER RATES OF A GIVEN ENGINE AND LOW-PRESSURE TURBINE WITH VARYING LOAD

Engine total water lines and turbine-pressure steam flow lines to the left. Steam consumption of combined unit, to the right. $A_1B_1C_1D_1$ engine operating with 500 kw, 1 000 kw, 1 500 kw and 2 000 kw low-pressure turbines, respectively.

For a definite quantity of steam passed by the high-pressure engine, the output of the latter, as determined by the resultant total water line when combined with a turbine of the capacity under investigation, is simply added to that developed by the turbine. In obtaining the latter from the total water lines, due allowance must be made for moisture in the engine exhaust and for the pressure drop between engine and turbine, usually taken at from one to two lbs. The combined output thus developed is compared with the

total steam passed by the high-pressure unit, determining the combined economy curves on the right, Fig. 3.

As will be observed, the effect of turbine size upon overall economy is, within certain limits, negligible, and may, therefore, be ignored where other conditions favor the choice of a particular turbine capacity. The reason for this close agreement in efficiency is quite plain. Assuming an engine of given size, there is, obviously, one turbine capacity that will give the best overall results. Variation either way from this best turbine size, will cause the engine performance either to improve or decline, as the case may be, the turbine economy being affected in the opposite direction. Thus, for a given departure from the best turbine capacity, the improvement in one element offsets the decline in the performance of the other, maintaining the net results virtually constant within a fixed range.

Large non-condensing turbines have not hitherto been regarded as competing with non-condensing Corliss compound engines, since the high-pressure piston engines have performed very efficiently. Improvements in the design of the turbine for non-condensing work have, for all practical purposes, overcome the advantage previously possessed by the steam engine. In brief, these results have been accomplished by increased speed ratings and better steam distributions. Tests made three years ago on a 600 kilowatt non-condensing turbine (obviously of the earlier design), proved the disparity between its performance and that of a first-class Corliss compound non-condensing engine to be less than five percent. Later modifications have virtually placed the steam consumption of the large non-condensing turbine on a parity with the engine; and with oil, supplies, maintenance and investment in its favor, the large non-condensing turbine should logically be preferred to the reciprocating engine. Reduction of internal windage losses, is imperative in the non-condensing turbine, if good efficiencies are to be realized. The drum construction is known to suffer much less loss than the disc type, and is therefore superior. Paradoxical as it may appear, the high-pressure section, which is the most inefficient section of the complete expansion turbine, becomes quite satisfactory in the non-condensing unit. The explanation is simple, inasmuch as the quantity of steam flowing is doubled (with the available energy being halved), so that the ratio of leakage area or annulus to blade height, is very much more favorable to economy.

The advanced construction of large non-condensing turbines, is shown in detail in Fig. 4, incorporating many interesting improvements in working parts. The smaller non-condensing tur-

bines are not capable of making quite so favorable a showing on the basis of heat efficiency but, as now well understood, the steam economy in small operations is not so vital a factor as in the case of large prime movers.

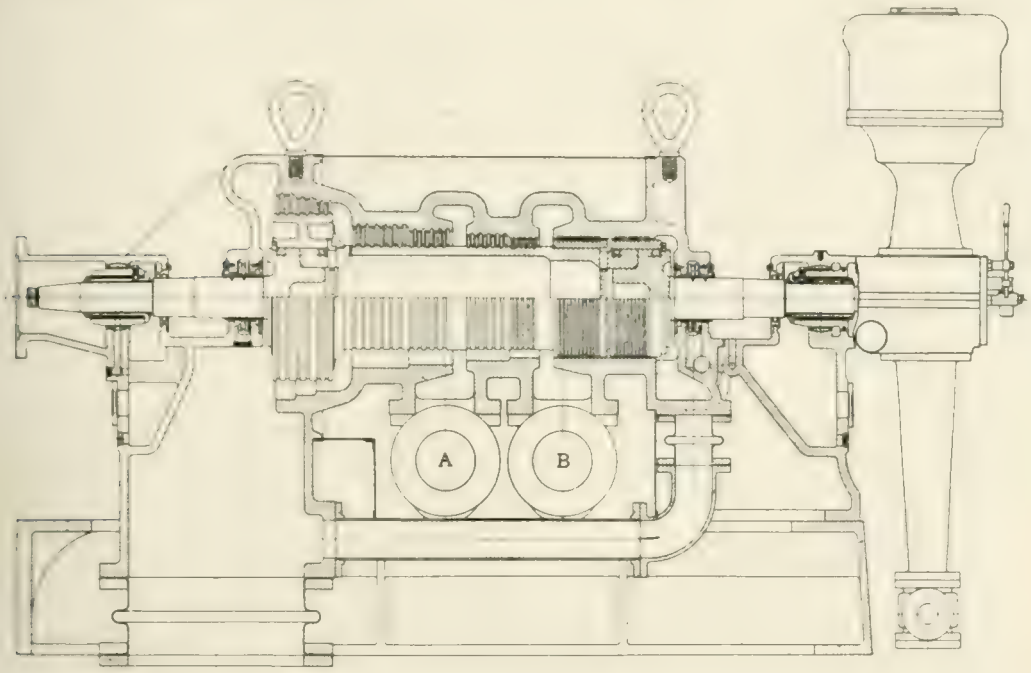


FIG. 4—NON-CONDENSING REACTION TURBINE, 1 000 KW CAPACITY

The sustained efficiency of the turbine, as compared with the vagaries of the engine, needs no emphasis, and it is probable that any lead the engine may possess initially, will disappear unless the engine is constantly groomed and cared for. The spindle of a 1 000 kilowatt non-condensing unit is shown in Fig. 5.

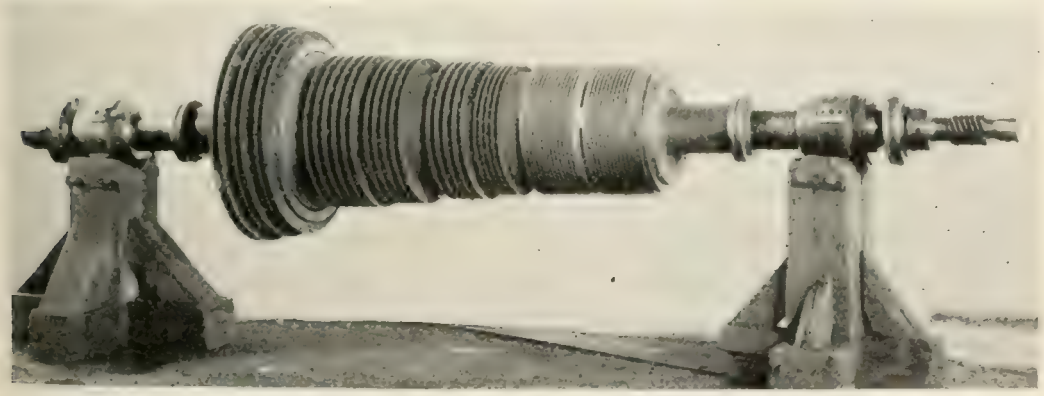


FIG. 5—ROTOR OF NON-CONDENSING REACTION TURBINE

In regard to special applications of the steam end, the design of the automatic bleeder turbine is undoubtedly the most unique of recent developments. It is arranged to profitably serve a combination of independently varying light and heat loads which may be supplied from a single station. The readiness with which the turbine

is adapted to automatic bleeding operation will be appreciated from Fig. 6, showing a section through such a turbine. The departure from standard construction consists in the main, of locating a diaphragm *A* between the intermediate and low-pressure stages, the flow of steam being regulated by a gravity controlled valve *B*. Live steam is admitted at *C* and, passing through the high-pressure and intermediate sections, part is diverted to the heating system through the connection shown, the surplus passing through the low-pressure section to the condenser. It will be seen that when the pressure in the heating system rises above any predetermined amount, as would occur with a decreased heating load (according to the counterbalancing weight used), the valve *B* will be elevated and more of the

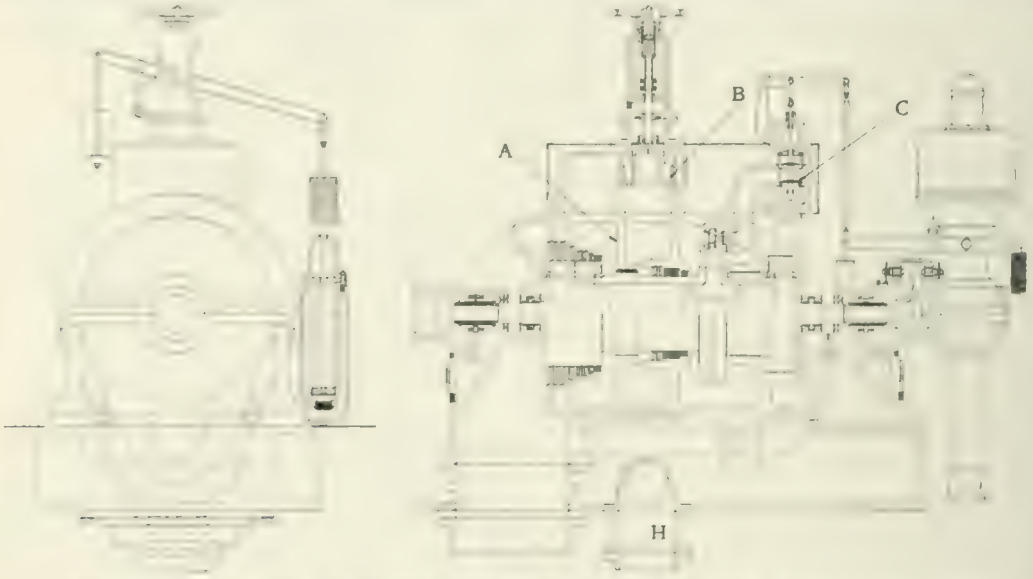


FIG. 6—AUTOMATIC BLEEDER TURBINE FOR COMBINED ELECTRICAL AND HEATING LOADS

steam will continue through the low-pressure section of the turbine, developing there an additional amount of work.

There are many manufacturing establishments, and likewise central power plants, where a joint demand for heat (from low-pressure steam) and light occurs. With the growing tendency to proportion the plant layout economically, and with provision for automatic regulation for all variations kept in view, the value of this design will at once be appreciated. Presumably the importance attached to this design will become more plain when we examine the characteristics of the bleeder type. In addition to the economy and elasticity of application, a wide range in the selection not only of the unit itself, but also of its complementary condenser, is readily seen. To facilitate a proper grasp of its economic possibilities, the triangular chart, Fig. 7, has been developed, enabling a ready ap-

preciation of the relation between the steam bled, the steam supply to turbine (otherwise draft on the boilers) and the quantity passed to the condenser for a given power load sustained by the unit. These curves have been plotted against brake horse-power on the horizontal, and weight of steam bled on the vertical scale. The solid lines extending up and to the left, are lines of constant steam supply and show the increase of available power with decreased bleeding. As will be observed, this is a straight line relation within a certain range, the power output increasing at a constant rate as the amount bled decreases, or what is the same thing,

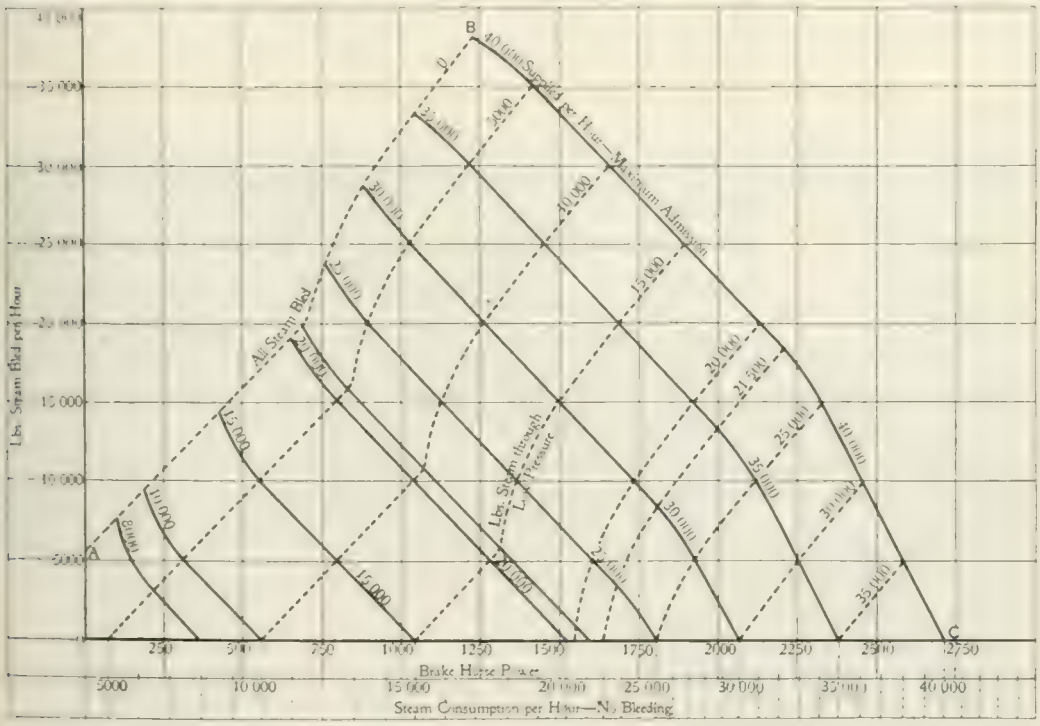


FIG. 7—RELATION OF STEAM DISTRIBUTION AND POWER LOAD WITH VARIABLE BLEEDING DEMAND, AUTOMATIC BLEEDER TURBINE

1 000 kw automatic bleeder turbine, 150 lbs. dry and saturated steam, 28 in. vacuum, 5 lbs. gauge bleeder pressure, 1 500 r.p.m.

as the amount passing through the low-pressure stages increases, as shown by the dotted lines extending up to the right. It will be noted that as the latter reaches a certain value, i. e., about 21 500 lbs., the slope of both the dotted and solid lines becomes steeper, and correspondingly the rate of increase of power output is diminished. This is due to the opening of the secondary overload valve, as the bleeder turbine is designed for a normal bleeding demand and the low pressure stages accordingly are proportioned to pass a certain quantity of steam. Therefore, when this is exceeded, the turbine output, while still increasing, does not do so at so fast a rate.

To complete the explanation, a supplementary scale, Fig. 7, has been added below that of the brake horse-power, which gives at a glance the total steam consumption of the unit operated strictly condensing (a limiting condition). The other two interesting limits are lines *AB* and *BC*. The line *AB* gives total steam with no work developed in the low-pressure cylinder; i. e., all steam bled at the particular load, and *BC* establishes the boundary for maximum power which may be developed when a predetermined amount of steam is bled. It should be noted that when all steam is bled, as shown by the limiting line *AB*, there is a small difference between the total amount supplied and that accounted for by the quantity bled. On first thought it would seem these should be equal, but owing to the construction employed, a small portion of the steam

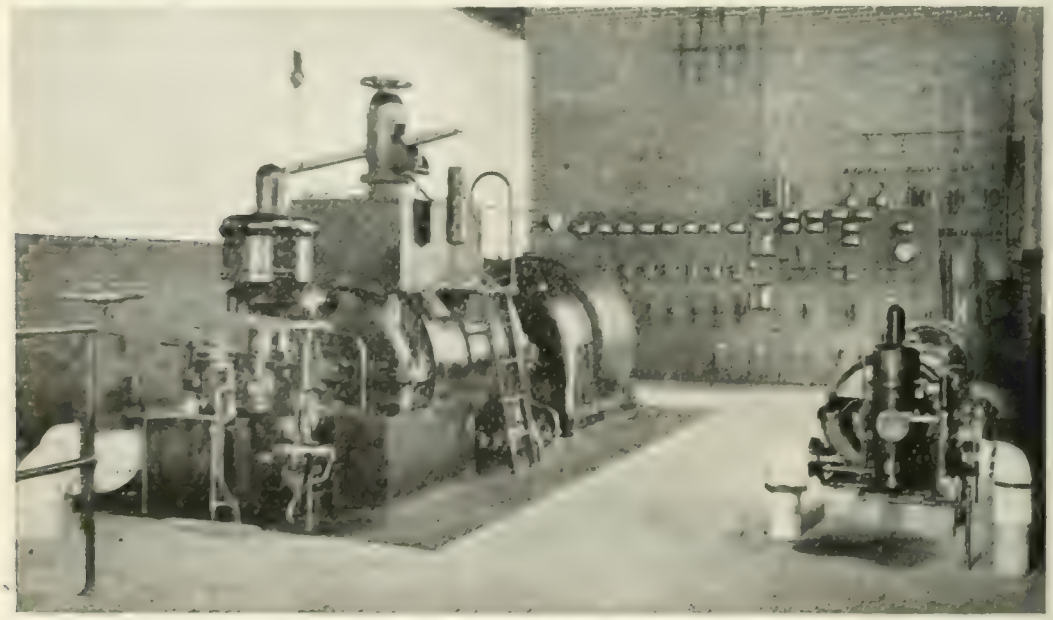


FIG. 8—750 KW AUTOMATIC BLEEDER TURBINE
International Harvester Company, Springfield, Ohio

leaks past the packing into the low-pressure section, which explains the apparent discrepancy.

A careful study of the chart will furnish a broader view of bleeder turbine characteristics and will considerably assist in the choice of the condenser capacity best suited to the particular set of conditions. In the non-automatic bleeder the performance could not be so clearly demonstrated as the bleeding is not so closely related to the internal operation of the turbine. This chart obviously applies only to the capacity noted and for the conditions set forth. Evidently a change takes place for any variation in size or nature of operation.

Similar conditions are undoubtedly bound to arise in large un-

dertakings, and the point in question will manifestly be the feasibility of providing large turbines for the purpose. This consideration has already been given due thought, with the result that plans have been prepared for accommodating large turbines to the work, and a diagrammatic illustration of the double-flow construction accordingly arranged is shown in Fig. 9. These simple illustrations serve to show how fortunately the steam turbine has lent itself to the march of the world's progress.

APPLICATION TO POWER HOUSE AUXILIARIES

In the development of the turbine, attention was first paid to the building of main units where it was perceived that the reciprocating engine had its limitations. Evidently almost as many factors commend the turbine for auxiliary drive as for the large prime mover. They are, in brief, uniform rotation, absence of vibration

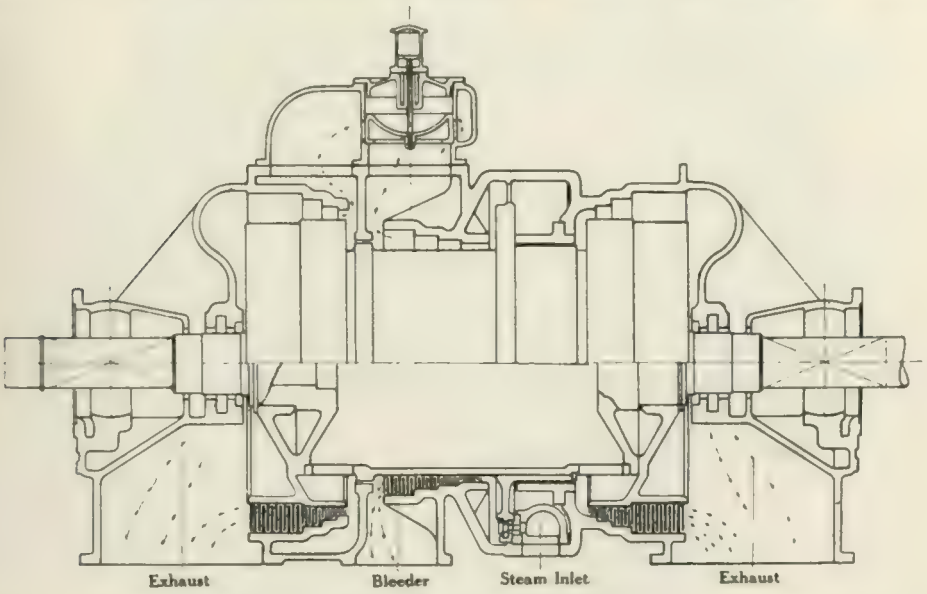


FIG. 9—ARRANGEMENT OF DOUBLE-FLOW AUTOMATIC BLEEDER TURBINE FOR LARGE CAPACITIES

and shock, elimination of oil in the exhaust, reduced floor space and decreased maintenance and investment charges. Consequently turbines are now being successfully used to drive exciter sets, condenser air and circulating or evacuating pumps, centrifugal boiler feed pumps, and blowers for mechanical draft.

Direct-Current Turbine Generator Sets for excitation purposes naturally followed in the wake of the large alternator, in spite of the fact that the first turbine unit generated direct current. The commutator problem was the most difficult to overcome in direct-current work, and therefore this type has proceeded slowly. While this feature has been completely solved in all small sizes, the use of the large, direct-coupled generating unit is still open to debate.

There are various types of small turbines, but they are, in practically every case, of the impulse class since the reaction type does not lend itself commercially for small powers. Simplicity being the byword in the design of small turbines, the axial reëntry principle has been employed, the main feature being that a single-bladed wheel only is required, multiple pressure and velocity drop being attained through reëntry nozzles and passages. This construction has been in general use for some time, and hence is familiar to power plant operators.

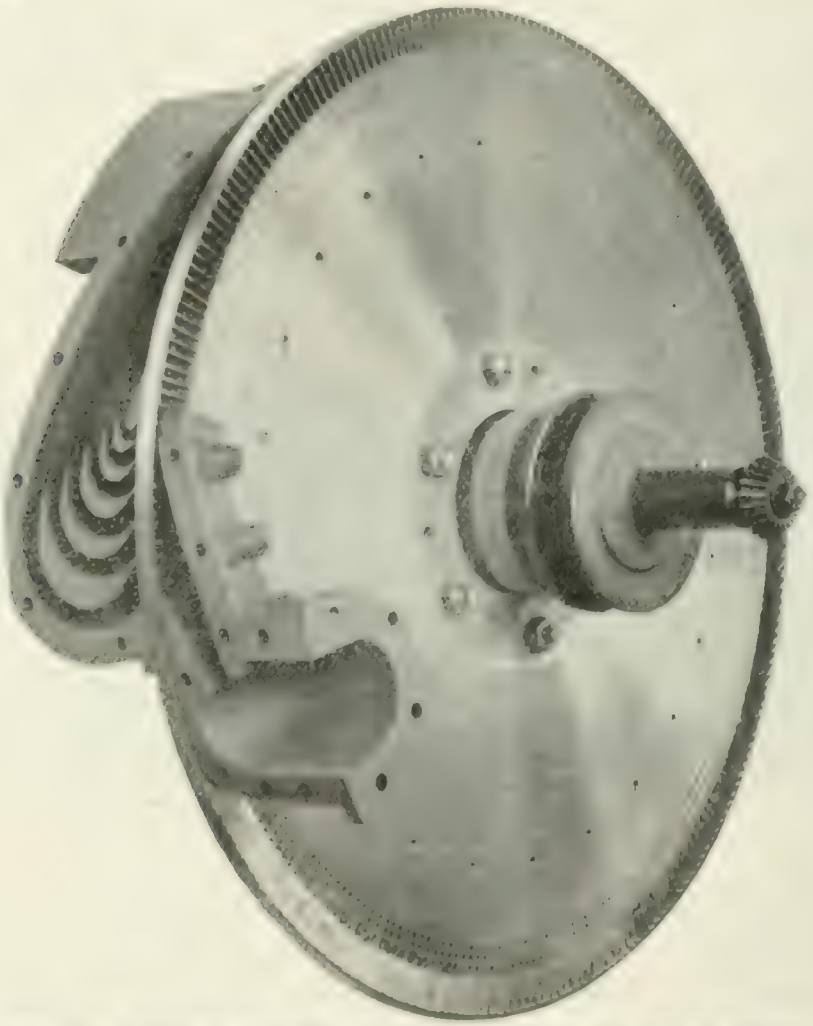


FIG. 10—NOZZLE, WHEEL AND REVERSING PASSAGE, RE-ENTRY TYPE TURBINE

In this arrangement relative changes in the ports, for varying operating conditions, is carried out in a most simple manner, either by increasing or decreasing the nozzle and reversing chamber areas and angles according to requirements, one set of castings thus being applicable to a wide variation of conditions. This is extremely important in small sizes on account of the greater possible range of working pressures, and such characteristics as noted are necessary in

order that they may be properly taken care of. The nozzle block and reversing chambers shown in Fig. 10 (a detail of a 50 kw exciter set) exhibit the reëntry principle. The complete unit is shown in Fig. 11.

Although *centrifugal pumps* have been used since 1880 or possibly a little earlier for working against high heads, they came into vogue in the *boiler plant* only within the last five years. Centrifugal boiler feeders might conveniently be operated by electric motors, but the usual demand for exhaust steam for feed water heating requires that they be steam driven, hence the direct-coupled turbine unit. Owing to the relation of capacity, pressure and impeller diameter, the centrifugal pump is not suited to small capacities and high head, and this design may therefore be employed only in plants

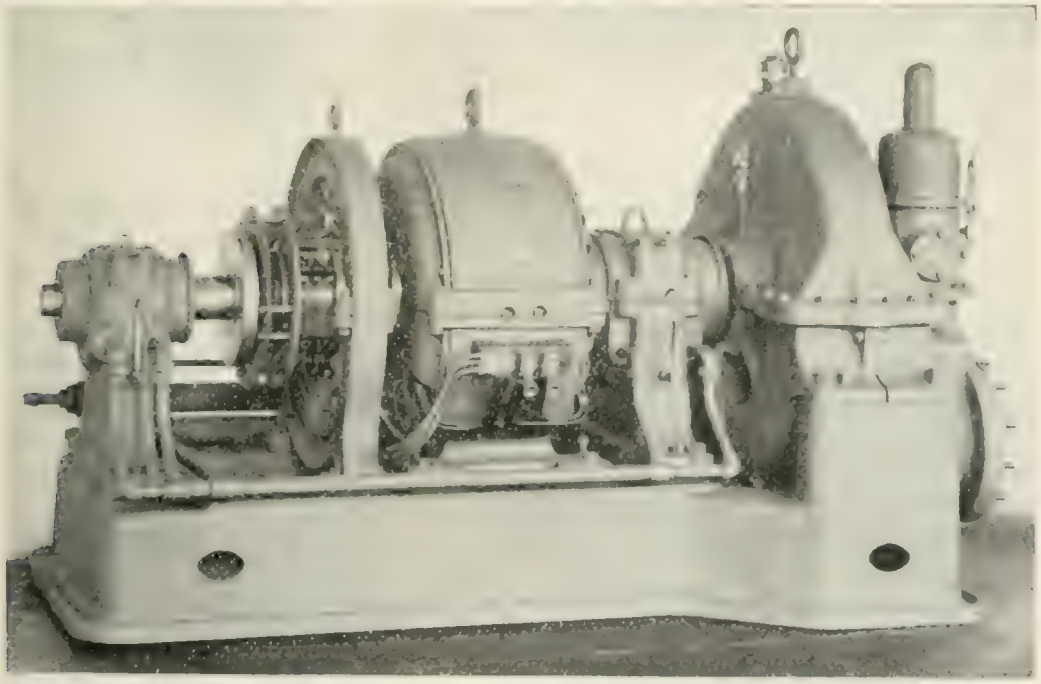


FIG. 11—100 KW, DIRECT-CURRENT GENERATOR DRIVEN BY RE-ENTRY TYPE TURBINE

exceeding 2 500 boiler horse-power. Ordinarily in a steam turbine a stage is provided to create 50 to 70 lbs. pressure. Consequently in the neighborhood of 175 lbs. gauge pressure, a three-stage unit is required. A sectional exhibit of a three-stage pump and the driving turbine, is shown in Fig. 12 which displays fundamental simplicity in contrast with the multi-deck valve plunger pump. Difficulty with valve packing and of close governing has been obviated in this type. There is no definite way of comparing efficiencies, but it is reasonable to assert that where the centrifugal pump is operated beyond two-thirds of its rated load, it should excel in efficiency. Actual experience with the two types of boiler feeders should be a criterion by which to correctly judge them. One operator who installed the

centrifugal type of apparatus in 1906, has expended practically nothing so far for repairs. Another more comprehensive analysis is furnished by the following, which is in answer to an inquiry addressed

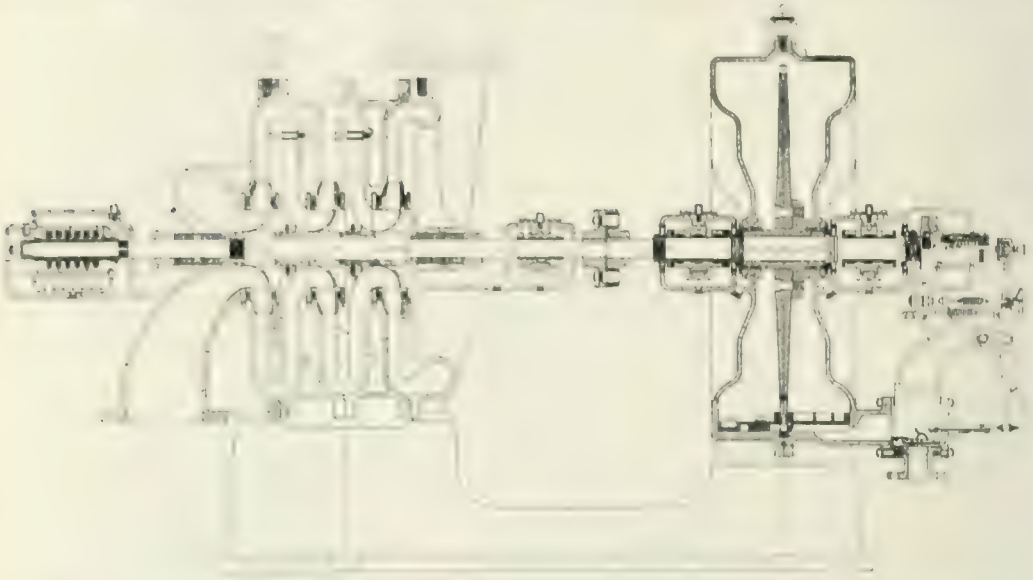


FIG. 12—TURBINE DIRECT-CONNECTED TO THREE-STAGE HIGH-PRESSURE CENTRIFUGAL PUMP



FIG. 13—TURBINE-DRIVEN CENTRIFUGAL BOILER FEED PUMP

to a large central station operating both centrifugal and reciprocating boiler feeders:

"The repairs on the turbine-driven centrifugal feed pump installed in 1906, have been $8 00 for new babbitts. It has been in constant operation.

and the throttle has been closed only two or three times, the total stoppage amounting to less than three hours in two years or more.

"The repairs on two outside packed plunger pumps have averaged $376.58 for the past three years. They now need extensive repairs.

"The engineers in the station have developed a dislike for plunger pumps due solely to the record made by the turbine-driven centrifugal pump in our station. The principal items on the repair account of the plunger type of pump, are packing boxes, new valve parts and machine work on old valve parts. We find that the four boxes on each pump have to be packed about five times each year at a cost of about $10 each. This makes an item of $200 for packing alone, or $400 for both pumps. You, of course, understand that the pumps have to be lubricated and as it is our practice not to let any greasy exhaust get into our feed water, all the exhaust from these pumps is put through a closed heater. With the turbine-driven pump, there is no oil in the exhaust, and this we put into an open heater, thereby making considerable saving over the operation of the plunger type, even if we admit that both types take the same amount of steam. It is our opinion that the turbine-driven pump takes considerably less steam for the same service, but we have made no tests and have no figures of our own to substantiate this. Roughly, I would say that the turbine took 4/10 as much steam as the plunger pumps for the same duty."

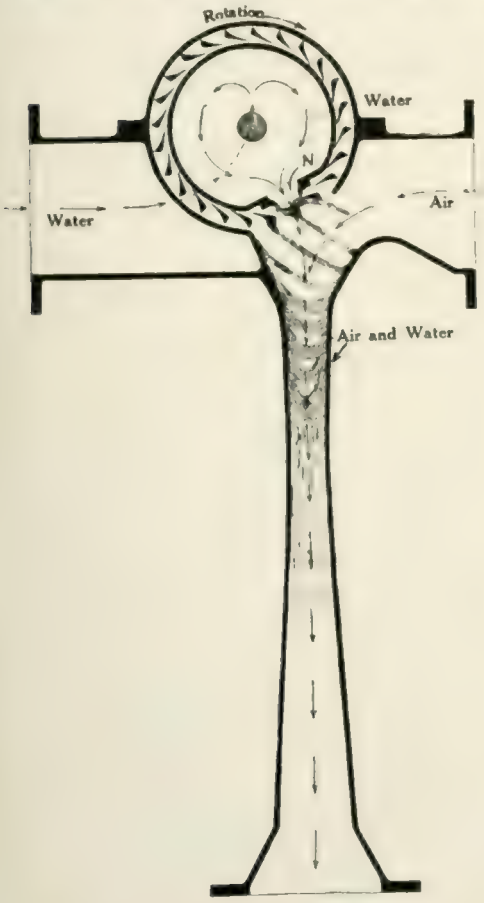


FIG. 14—SECTION THROUGH LEBLANC AIR PUMP, SHOWING ACTION OF WATER PISTONS

An installation view of the type of pump above discussed is given in Fig. 13.

A turbine-driven vacuum air pump evidently involves the most radical departure from preceding power plant practice. An air pump employing water jets or sheets to eject or evacuate the air from the condenser, was invented by M. Leblanc, and is capable of being operated at the high speeds suitable for direct connection to small turbines. The principle is simple. An impeller, Fig. 14, with shallow blades, imparts a high velocity to sheets of water collected in passing the nozzle *N*, and which, ejected into the air passage, entrap layers of air. By means of a diffuser, its velocity is transformed into pressure, forcing the mixture of air and water out against atmospheric pressure, or a somewhat greater head, as the case may demand. The advantages of this type are quite plain. We again evade the necessity of closely fitting parts and rubbing sur-

faces, requiring lubrication and frequent adjustment and the separation of the oil from the exhaust steam where used in connection with an open heater. As there are no reversals in operation, the harmful effect of clearances in the reciprocating air pump is avoided and a low absolute back pressure may be maintained. The operating characteristics of the Leblanc and the reciprocating air pumps are divergent, which may be best illustrated in the manner shown in Fig. 15, determined from actual test. Above the line *AA*, the Leblanc pump would always be superior to the reciprocating pump,

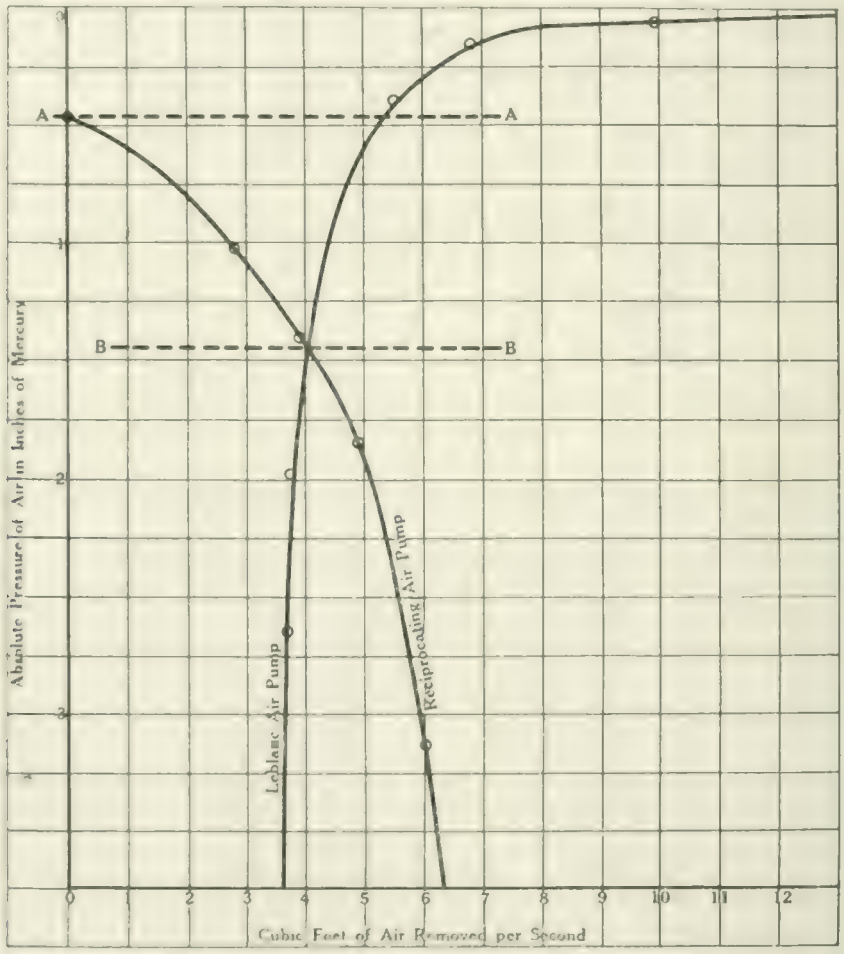


FIG. 15—CURVES SHOWING COMPARISON OF AIR REMOVED BY RECIPROCATING AIR PUMP AND LEBLANC AIR PUMP

even if its power consumption were in excess. If the latter were identical in the two cases, the Leblanc pump would always be more efficient when working in the region above *BB*, and inferior below *BB*. The conditions for high vacuum service are generally such that the air tensions to be maintained are above *BB*, so that the question of power consumption is therefore not the final criterion. The question of air tension maintained, must also be considered.

Where condensers are used with steam turbines, the one-half inch lower air tension which would be secured with the Leblanc pump, would result in a decrease of two percent or more in the steam consumption of the turbine. This (considered together with

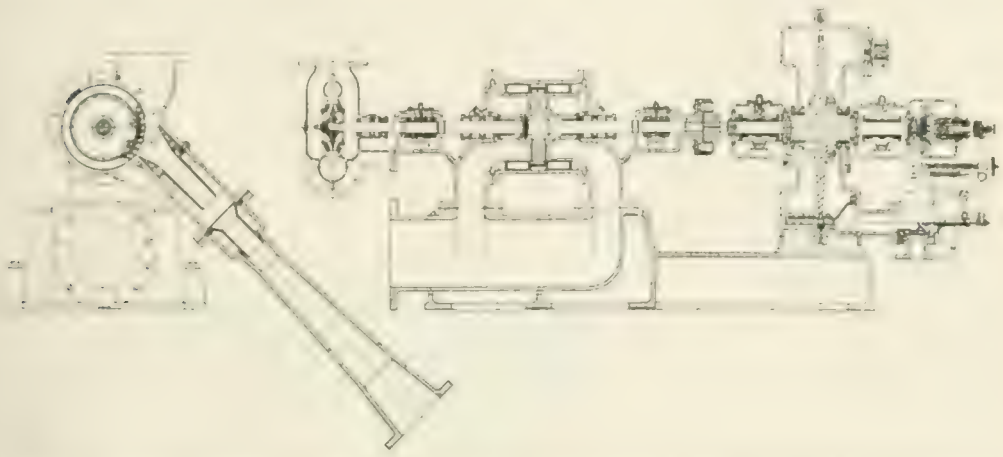


FIG. 16—SECTIONAL VIEWS OF TURBINE-DRIVEN AIR AND HOT WELL PUMPS

the use of the auxiliary exhaust in the feed water heater) may closely compensate for the whole power consumption of the condenser.

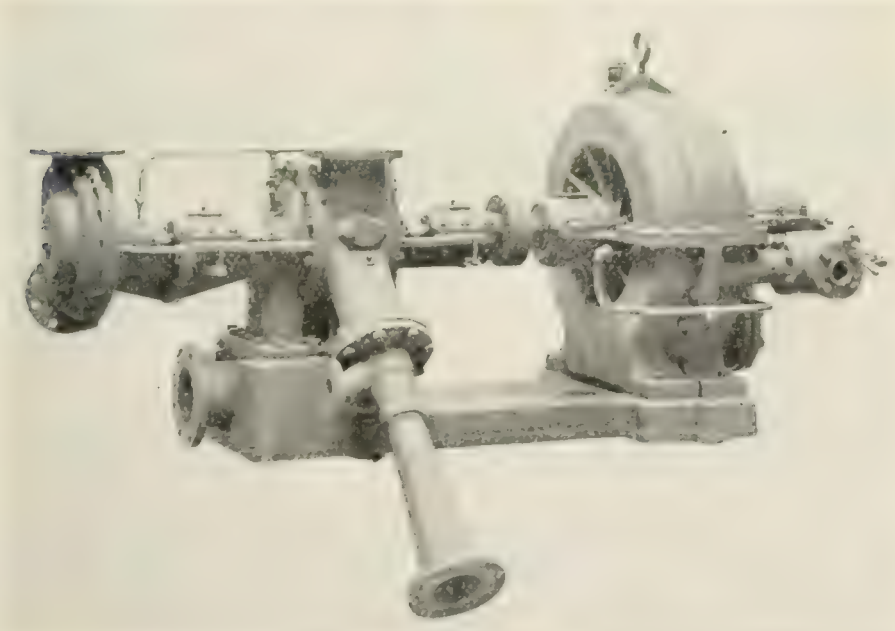


FIG. 17—COMPLETE UNIT, TURBINE-DRIVEN AIR AND HOT WELL PUMPS

The general conclusion to be drawn from both theory and practice, is that for high vacuum performances, the Leblanc pump, on account of the characteristics shown in Fig. 15, in nearly all cases will show a net saving in plant economy, either by giving a

better vacuum for the same power as would be required by a reciprocating pump, or by the reduced air tension in the condenser, making it unnecessary to circulate as much cooling water to maintain the same vacuum.

As an illustration, it is of interest to review the facts brought out in a recent installation of a surface condenser plant equipped with a Leblanc air pump. In this particular plant, high vacuum was desirable as the condensers were used in conjunction with

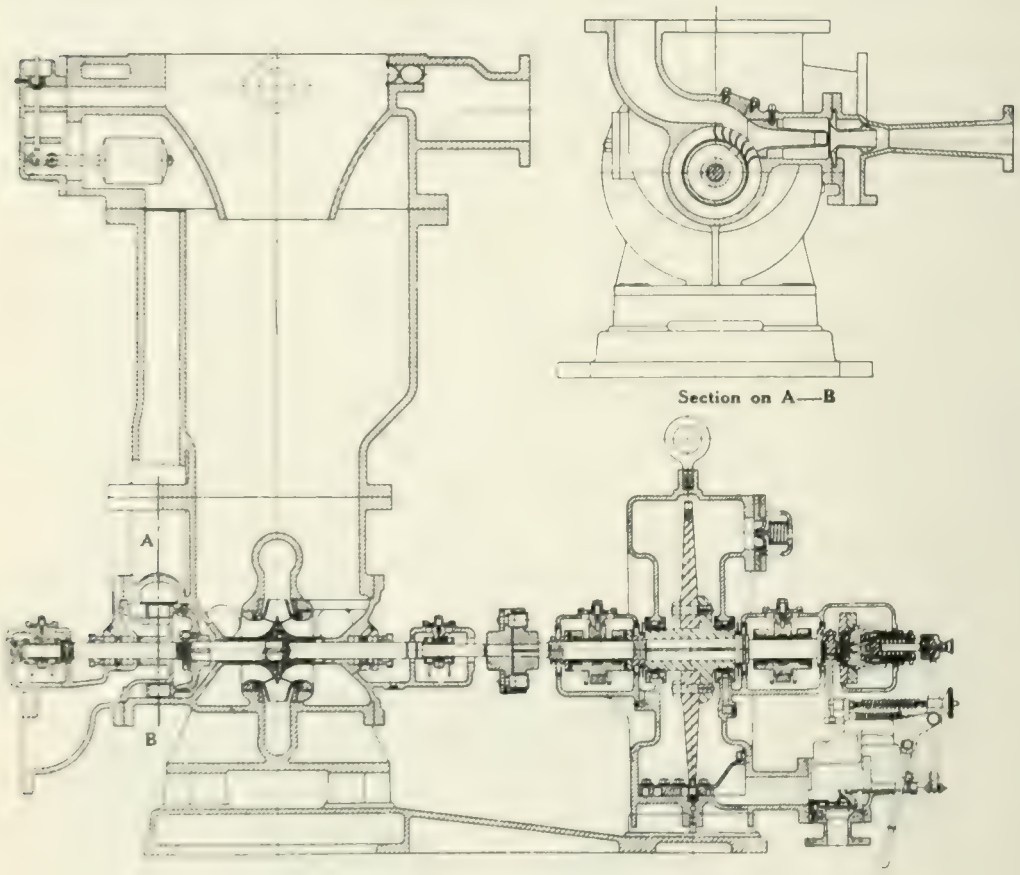


FIG. 18—TURBINE-DRIVEN LEBLANC JET CONDENSER
Showing a compact arrangement of air and water pumps

steam turbines. The reciprocating air pumps were giving fairly good results, but were not quite large enough, and it was decided to install greater pumping capacity, either by putting on larger air cylinders, purchasing a new reciprocating pump, or installing a Leblanc air pump. The Leblanc air pump for this work, while requiring 40 percent more power, had a capacity substantially the same as the reciprocating pump for a vacuum of approximately 28 inches of mercury, but with 29 inches of vacuum, its volumetric

capacity was practically three times that of the reciprocating pump, characteristically brought out in Fig. 15. The net result was that the Leblanc pump enabled the maintenance of one-half of an inch better vacuum under winter conditions, so that the bettering of the economy of the prime mover far offsets the slightly increased power consumption of the Leblanc air pump over that required by the reciprocating pump.

The unit shown in Fig. 16 has a hot-well pump attached, as would be employed in surface condenser work, or without the hot-well pump for barometric condensers. The compactness and simplicity of the assembled outfit is evident from Fig. 17. Heretofore the Leblanc air pump has been more commonly employed with low-level jet condensers, Fig. 18 showing an improved type especially designed to embody this principle. This equipment may be placed beneath the turbine, and thereby occupies no space outside of the boundary of the turbine proper, as the layout appended shows. A complete jet condenser and auxiliaries ready for installation, is given in Fig. 19.

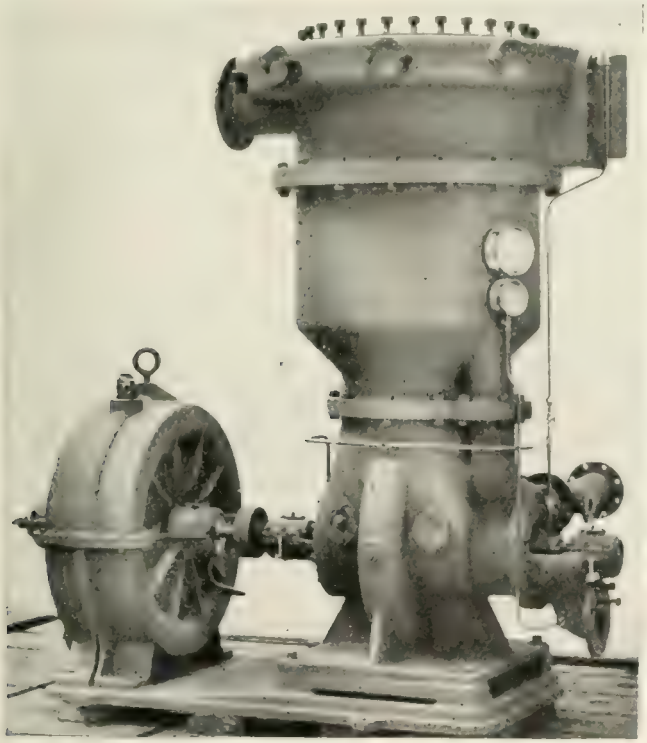


FIG. 19—LEBLANC CONDENSER AND AUXILIARIES

Mechanical draft has not in the past met with universal favor for boiler plant operation. A new condition is rapidly coming to the fore, manifesting itself in the nature of forcing boilers to double, and even treble their accustomed ratings to accommodate peak loads and still maintain good efficiencies in the boiler house during the hours of light load on the plant. High rates of driving boilers require forced draft. In the main, large "paddle-wheel" fans driven by small, high-speed engines, have been used in this service. The same trend which has influenced the replacement of the reciprocating engine in other classes of auxiliary

work, has already been observed in blower operation. On top of the other common advantages of the turbine which have been noted before, the shaking and racking of the blower casing, ducts and supports, is removed. The blower in its old form proves itself deficient for connection with the turbine in the present state of the art. A shallow blade construction with guide vanes for low-pressure work (as shown in the upper part of Fig. 20), propels the air with the least losses and power consumption. The vertical type is exhibited to indicate the flexibility of the turbine application. This specific design has been prepared for use aboard United States Torpedo Boat Destroyers for forcing air under pressure into the boiler room. A down draft duct from the deck connects with the blower intake, and the discharge is made directly into the room. The turbine in this position is most accessible, and it is also evident that this arrangement requires but a minimum of duct length and bends. In a similar way some special problems in land practice may arise which may be met by a corresponding design, although with the latitude permitted in power plants, a more standard construction will unquestionably be adopted.

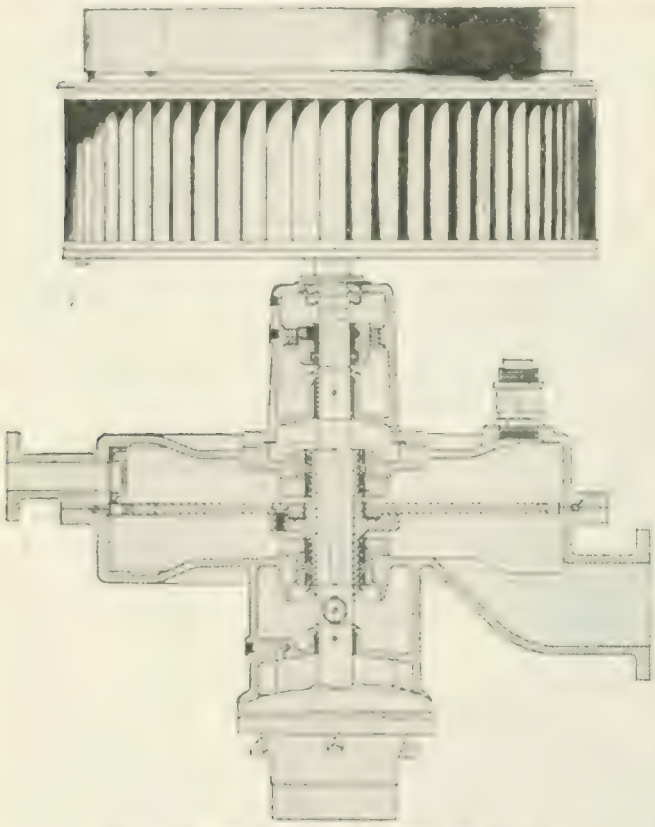


FIG. 20—TURBINE-DRIVEN BLOWER

Special vertical reëntry design for use on shipboard.

(*To be continued.*)

STANDARDIZATION

H. F. CHADWICK

A STANDARD, according to Webster's International Dictionary, is "that which is established as a rule or model by authority, custom or general consent." Standardization is a comparatively recent word, except in its application to chemistry. One of the best definitions is "the study and recognition of standard forms and qualities." There is, of course, nothing new in the idea. We have standards in literature and art, so that a book or painting which is of an acknowledged high quality is known as a classic. Again, in chemistry and medicine we have various standard compounds, and no one can question that enormous benefits have resulted to society from such adoption of standards. Again, consider the standards for weights and measures; no commerce or progress can be imagined without such systematization of what is meant between man and man.

Standardization improves ease, economy and expedition of production. When engineering products were almost entirely the result of manual labor it was not of very great importance what dimensions were prescribed, as it was as easy and economical to forge one particular size of simple forging as another; but with the advent of machinery, whether rolling mills for producing rails or sections, or automatic machines for producing screws, the maintenance of one particular type or pattern gradually came to be of almost paramount importance. More and more capital was being invested in machinery and plant, and it was increasingly important to the owners that such plants should be worked as continuously as possible at maximum efficiency, and with the least amount of departure from the particular sizes or shapes which such machines were designed to produce.

Practically all manufacturing concerns have found that they have designed many parts varying in unimportant details, largely because engineers and draftsmen had no standards to guide them, so that the list grew automatically without thought or benefit. Specifications of material were found to differ only in unimportant and trivial details. Some of the results of lack of system were:—

1—Unnecessary cost due to cost of tools and expense of constantly changing them for different orders.

2—Delay in production due to making new tools or changing them.

3—Impossibility of carrying stock.

Standardization has had a very appreciable effect on the cost of production. For ordinary commercial products, especially for details in common use and part manufactured products, cost of production is a primary consideration, and the greatest economy is realizable if all users and manufacturers can agree to accept the same standards of size and quality. It is found in practically all cases where standardization has been effectual that, after elimination of the initial cost of drawings and patterns, the manufacturing costs have shown a decided reduction; and it is a noticeable fact that, in cases where standardization has been adopted and departures therefrom subsequently made, the labor cost has been found to be considerably greater, even after deducting the cost of the new drawings and patterns.

There has been some opposition to standardization, the fear being expressed that it would discourage individuality of design, and that there might be a tendency toward the stereotyping of forms which ought to be varied to meet requirements as they might arise.

In this connection, Mr. Chas. F. Scott says:—

"As a foreign engineer expressed it to me, the engineer in his country was somewhat of an artist. He wanted to build up a new plant according to his own ideas. If he simply followed somebody else there was nothing individual in his effort, any more than an artist would deserve merit if he simply copied someone else's pictures. He wanted to build up a new system, and if he could find a voltage or a frequency that was a little better adapted to his particular plan, according to his opinion, why that was undoubtedly the thing to use."

The individuals who express these fears overlook the fact that usually standardization does not affect assembled parts, in which the individual mind has as full play as ever. It has not been and should not be the policy to adopt standards once for all; it is recognized that new forms must be added and modifications in design made from time to time as they are shown to be proper and desirable. Provided standardization is not effected too soon or adhered to too tenaciously, the advantages decidedly overbalance the disadvantages. It must always be remembered, however, that, while the economic advantages of standardization of particular products of manufacture are obvious and immediate, the evils of stereotyping practice and interfering with improvement become apparent only gradually.

A general standardization is possible in three classes of cases:—

1—There can be a limitation of the number of forms and dimensions of the simpler elements of structures or machines, still allowing sufficient latitude of design to meet all ordinary requirements.

2—There can be standardization in the sense of fixing those physical properties and qualities of materials of construction which by general experience have proved best in practice, and in specifying the tests and regulations for inspection which users of material may demand before acceptance. It obviously simplifies the operations of manufacturers if goods can be ordered to a standard specification instead of to discrepant specifications prepared by different engineers.

3—Lastly, in the case of some largely used machines, it is possible to lay down general standard regulations as to design and accuracy of workmanship, which will enable manufacturers to foresee the demands which they will have to supply.

HISTORICAL

Sir Joseph Whitworth in 1841 made a notable step with his standards of screw threads. Very little more was done for sixty years. Early in the history of the United States Government, provision was made for the adoption of suitable standards of length, mass and capacity. The Treasury Department, which had charge of the work, in providing copies of these standards for the several states, through the Office of Weights and Measures, was also obliged to go into the matter of thermometric standards. But beyond this limited scope of the government's activities, nothing further was done up to a comparatively recent time. The Office of Weights and Measures, during the last years of its existence (at the time of the beginning of the electrical industries), began to equip itself for the testing of electrical standards, especially of resistance and e.m.f. The gigantic growth of scientific, manufacturing and commercial interests, requiring the substitution of exact for rule-of-thumb measurements and the introduction of interchangeable methods in manufacturing, revealed the poverty of standardizing facilities that existed in this country. The need of the establishment of a National Bureau of Standards was agitated, and on March 3, 1901, the Congress appropriated funds for the construction and equipment of laboratories and the maintenance of

a scientific staff. The Bureau of Standards was accordingly created on July 1, 1901, as a branch of the Department of Commerce and Labor. The following extract from Bureau Circular No. 6, dated February 20, 1906, explains the scope of the work of the department:—

"The Bureau will furnish such information concerning standards, methods of measurement, physical constants, and the properties of materials, as may be at its disposal, and is authorized to exercise its functions for the government of the United States, for state or municipal governments within the United States, for scientific societies, educational institutions, firms, corporations or individuals engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments. For all comparisons, calibrations, tests or investigations except for those performed for the government of the United States or state governments, a reasonable fee will be charged."

The papers and circulars issued by the Bureau cover a wide range of subjects in the field of physical measurements and have been of great value to the scientific world.

The American Society of Mechanical Engineers was probably the first engineering society in the United States to recognize the value of standards, for in December, 1886, they adopted a standard for pipe and pipe threads. Since that time they have issued many important standards.*

The American Institute of Electrical Engineers has also been active along standardization lines. On January 26, 1898, there was a topical discussion at New York and Chicago on the subject, "The Standardization of Generators, Motors and Transformers."

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*The principal ones are as follows:
December, 1892. Standard Flanges.
August, 1893. Standard Methods of Conducting Locomotive Tests.
December, 1899. Standard Method of Conducting Steam Boiler Trials.
December, 1901. Standard Pipe Unions.
December, 1901. Standardization of Engines and Dynamos.
1—The standard sizes of units recommended.
2—The corresponding revolutions per minute for these units.
3—The sizes of shafts for the two classes of centre-crank and side-crank engines.
4—The length along the shaft required for the generator.
5—The height of axis of shaft over top of sub-base.
6—The width of top of sub-base.
7—Armature fit.
8—Overload capacity of engines and generators.
9—Brush holders.
10—Holding-down bolts, keys and outboard bearings.
December, 1902. Standard System of Testing Engines.
December, 1903. Specifications for Boiler Plate, Rivet Steel, Steel Castings and Steel Forgings.
May, 1907. Standard Proportions for Machine Screws.

As a result of the meetings the following notable committee was appointed to draw up standardization rules:—Francis B. Crocker, chairman; Cary T. Hutchinson, Arthur E. Kennelly, John W. Lieb, Jr., Charles P. Steinmetz, Lewis B. Stillwell, Elihu Thompson. The report of this committee, entitled "Standardization Rules of the American Institute of Electrical Engineers," was presented and accepted June 26, 1899. The rules were revised June 20, 1902, and again on June 26, 1907. On June 10, 1907, the "Standards Committee," a standing committee of nine members, was appointed. The work of the Institute will be mentioned again in connection with the International Electrotechnical Commission.

The American Society of Civil Engineers has not been as active in adopting standards, but has issued one important report on "Standard Rail Sections."

The American Society for Testing Materials has done splendid work thus far, and has admirably fulfilled the object of its organization as stated in the charter:—"The corporation is formed for the promotion of knowledge of the materials of engineering, and the standardization of specifications and the methods of testing."*

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*Since August 10, 1901, the following specifications have been adopted and issued:

1—Standard Specifications for Structural Steel for Bridges.
2—Standard Specifications for Structural Steel for Buildings.
3—Standard Specifications for Structural Steel for Ships.
4—Standard Specifications for Open Hearth Boiler Plate and Rivet Steel.
5—Standard Specifications for Bessemer Steel Rails.
6—Standard Specifications for Open Hearth Steel Rails.
7—Standard Specifications for Steel Splice Bars.
8—Standard Specifications for Steel Axles.
9—Standard Specifications for Steel Tires.
10—Standard Specifications for Steel Forgings.
11—Standard Specifications for Steel Castings.
12—Standard Specifications for Wrought Iron.
13—Standard Specifications for Foundry Pig Iron.
14—Standard Specifications for Cast-Iron Pipe and Special Castings.
15—Standard Specifications for Locomotive Cylinders.
16—Standard Specifications for Cast-Iron Car Wheels.
17—Standard Specifications for Gray-Iron Castings.
18—Standard Specifications for Malleable Castings.
19—Standard Specifications for Staybolt Iron.
20—Standard Specifications for Hard-Drawn Copper Wire.
21—Standard Specifications for Cement.
22—Standard Classification of Structural Timber.
23—Standard Specifications for Yellow-Pine Bridge and Trestle Timbers
24—Standard Test for Fireproof Floor Construction.
25—Standard Test for Fireproof Partition Construction.
26—Standard Abrasion Test for Road Material.
27—Standard Toughness Test for Macadam Rock.
28—Standard Methods of Testing.

The "National Electrical Code," which has been one of the greatest influences toward standardization, was originally drawn up in 1897 as the result of the united efforts of the various insurance, electrical, architectural and allied interests which, through the National Conference on Standard Electrical Rules, composed of delegates from various national associations, unanimously voted to recommend it to their respective associations for approval or adoption.*

The International Association for Testing Materials has done excellent work in standardizing testing methods. The objects of the association, as stated in its by-laws, are as follows:

"The development and unification of standard methods of testing; the examination of the technically important properties of materials of construction and other materials of practical value, and also the perfecting of apparatus used for this purpose."

The sixth Congress of the Association will be held in the United States in the autumn of 1912, and as the president of the Association is chosen from the country where the Congress is held, Dr. C. B. Dudley, of Altoona, chemist of the Pennsylvania Railroad, was elected president at the last Congress. After his untimely death, Dr. Henry M. Howe, of Columbia University, was elected in his stead.

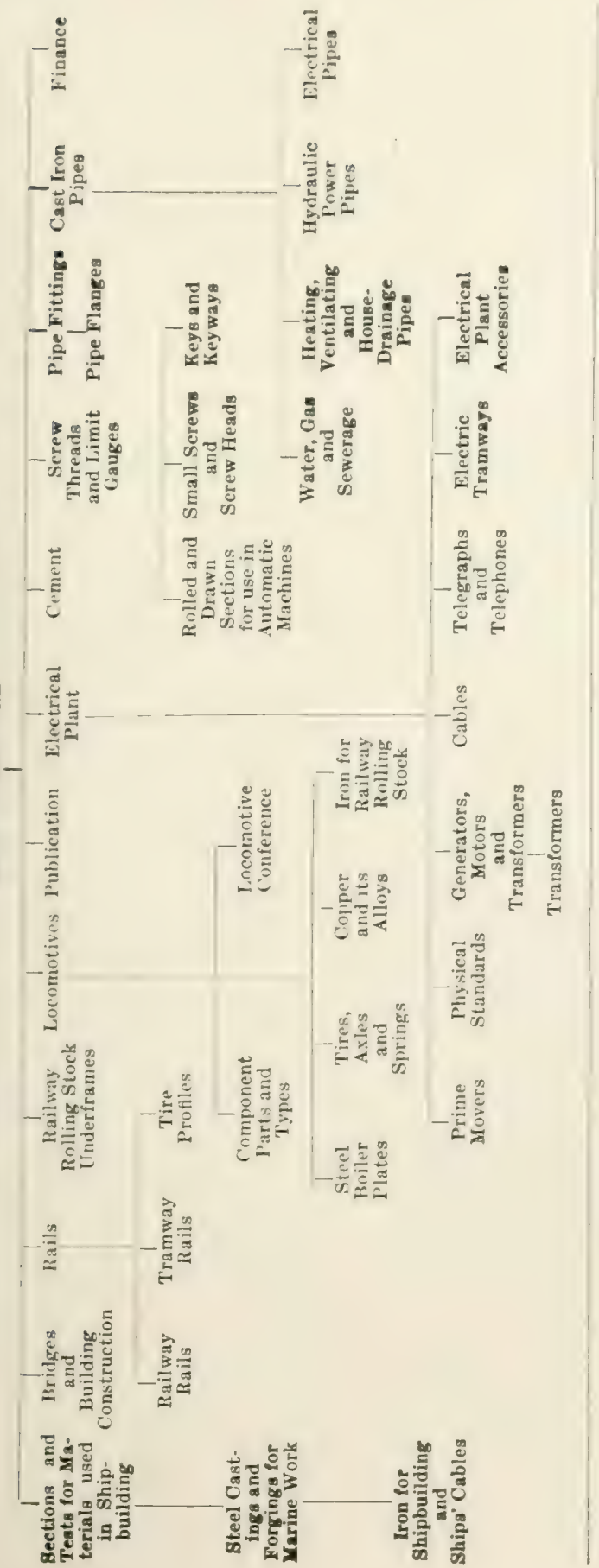
In Great Britain the value of standards was not appreciated as early as in the United States. Since 1901, however, there has been cooperative work among the various engineering societies, endorsed by the government, which has resulted in national standards. This is decidedly in advance of anything accomplished in the United States. The Engineering Standards Committee of Great Britain was originated in January, 1901, as the result of a motion by Sir John Wolfe Barry at a meeting of the Council of

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*The associations represented in the National Conference were as follows:—

American Institute of Architects.
American Institute of Electrical Engineers.
American Society of Mechanical Engineers.
American Institute of Mining Engineers.
American Street and Interurban Railway Association.
Associated Factory Mutual Fire Insurance Companies.
Association of Edison Illuminating Companies.
International Association of Municipal Electricians.
National Board of Fire Underwriters.
National Electric Light Association.
National Electric Contractors' Association.
National Electric Inspectors' Association.
The Underwriters' National Electric Association.

TABLE I—THE ENGINEERING STANDARDS COMMITTEE



the Institution of Civil Engineers. It is supported by the following bodies:—

The Institution of Civil Engineers.

The Institution of Mechanical Engineers.

The Institution of Electrical Engineers.

The Institution of Naval Architects.

The Iron and Steel Institute.

There are thirty-nine committees, with a total membership of nearly three hundred, engaged in the discussion, preparation and publication of standards. Table I, giving the sub-divisions of the main committee, shows what a wide range of subjects have been considered.

In Germany, the Society of German Electrical Engineers (Verband Deutscher Elektrotechniker) adopted in 1903 their "Standards, Regulations and Directions" (Normalien, Vorschriften und Leitsätze des V. D. E.). These rules

are similar in scope and arrangement to the Standardization Rules of the American Institute of Electrical Engineers.

The International Electrotechnical Commission, of which much is expected in the way of international standardization, was the direct result of the International Electrical Congress held in St. Louis in 1904. The Commission was formed in London on June 27, 1906, its object being the standardization of nomenclature and ratings of electrical apparatus and machinery. The following countries were represented:—Austria, Belgium, Canada, France, Germany, Great Britain, Holland, Hungary, Italy, Japan, Switzerland, Spain and the United States; Denmark, Norway and Sweden had accepted the invitation, but did not send delegates. Since the formation of the commission, national committees have been appointed in several countries, and much progress has been made toward the standardization of nomenclature and symbols. At the last meeting of the Commission at Turin, September, 1911, at which fifty-one delegates were present representing nineteen countries, international lists of terms and symbols were adopted provisionally, and the three symbols used for the algebraical expression of Ohm's law were adopted definitely. Definite action was taken on the direction of phase rotation in alternating-current diagrams and the report of the Brussels conference in relation to international rating of machinery was adopted. Tentative plans have also been submitted for international standardization in the direction of stationary direct-current generators, and motors for continuous service constant potential operation. The following countries are now represented by national committees on the Commission:—Argentina, Austria-Hungary, Belgium, Canada, Denmark, France, Germany, Great Britain, Italy, Japan, Mexico, Spain, Sweden and the United States. The committee from the American Institute of Electrical Engineers has been very active in working up and submitting suggestions to the Commission. It is believed that the Turin meeting will mark an epoch in the history of international electrical standardization.

STEAM ELECTRIC POWER PLANTS*

THEIR DESIGN, CONSTRUCTION AND OPERATION

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Westinghouse, Church Kerr & Company

ONE main principle underlies the design, construction and operation of all power plants, and this is the requirement that the plant shall produce a given amount of useful power, under the conditions imposed, for a term of years, for the least total cost, including all direct and indirect expenditures. These expenditures include not only the direct operating and maintenance charges, but also fixed charges on the total amount invested in the plant and all costs of interruptions to service that could have been prevented by investments in more or different equipment. A study of costs is therefore a key to the design of a power plant for any purpose.

The present discussion is limited to steam turbine driven electric plants using bituminous coal for fuel.

Even when limited to this class, there are so many factors involved, that each plant is still necessarily an individual study and no general rules governing all cases can be formulated. Irrespective of whether such a power plant is to be used for a coal mine, a public service utility or a factory, the most important conditions which govern the design and construction are as follows:

Character of Load to be carried. (High or low load factor, steady or fluctuating).

Location of Plant with reference to fuel and water supply.

Local Conditions affecting the dimensions of the building and the construction of foundations and flumes.

Relative Costs of available material and apparatus.

Fitness of Various Types of apparatus to the duty to be performed.

Costs of Fuel and Water.

Proper Relation Between Operating Costs and Fixed Charges, under the conditions imposed.

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*Condensed from a paper read before the Engineers' Society of Western Pennsylvania.

TABLE I—COST OF STEAM TURBO-ELECTRIC GENERATING STATIONS.

From 2 000 to 20 000 kilowatts capacity, based on maximum continuous capacity of generators at 50 degrees C. rise.

	DOLLARS PER KW High	Low
Preparing Site—Dismantling and removing structures from site, making construction roads, tracks, etc.	$ 0.25	$ 0
Yard Work—Intake and discharge flumes for condensing water, railway siding, grading, fencing sidewalks, etc.	2.50	1.00
Foundations—Including foundations for building, stacks and machinery, together with excavation, piling, waterproofing, etc.	6.00	1.00
Building—Including frame, walls, floors, roofs, windows and doors, coal bunker, etc., but exclusive of foundations, heating, plumbing and lighting	12.00	4.00
Boiler Room Equipment—Including boilers, stokers, flues, stacks, feed-pumps, feed-water heater, economizers, mechanical draft and all piping and pipe covering for entire station except condenser water piping	24.00	12.00
Turbine Room Equipment—Including steam turbines and generators, condensers with condenser auxiliaries and condensing water piping, oiling system, etc.	22.00	12.00
Electrical Switching Equipment—Including exciters of all kinds, masonry switch structure with all switchboards, switches, instruments, etc., and all wiring except for building lighting	5.00	2.00
Service Equipment—Such as cranes, lighting, heating, plumbing, fire protection, compressed air, furniture, permanent tools, coal and ash handling machinery, etc., etc.	5.00	2.50
Starting Up—Labor, fuel and supplies for getting plant ready to carry useful load	1.00	0.50
General Charges—Such as Engineering, Purchasing, Supervision, Clerical Work, Construction Plant and Supplies, Watchmen, Cleaning up, etc., etc.	6.00	3.00
Total cost of plant, except land and interest during construction	$83.75	$38.00

Finally, there is the element of *Personal Preference of the Client*, which is the deciding factor in the selection between types or methods that may cost practically the same and are economically equivalent.

The unit generally used in comparing plant costs is the kilowatt capacity of the generators installed. As there is today some little confusion in defining the rating of large generators, attention is called particularly to the fact the figures given are based on the maximum continuous capacity of the generator or the output that the machine will give with a temperature rise not exceeding 50 degrees C. above the surrounding air temperature.

Table I shows probable limits of cost of stations of the class referred to, namely steam turbine driven, electric stations for all

purposes, using bituminous coal for fuel and having no other equipment in them except that necessary to generate alternating electric current efficiently.

Some of the group costs in Table I do not have any very specific relation to the kilowatt capacity installed in the plant and the probable range in such costs is a matter of experience with previous cases. This refers to such groups as "Preparing Site," "Yard Work," "Electrical Switching Equipment" and "Service Equipment." For instance, the main item of cost coming under the "Yard" group is generally that of condensing water flumes exterior to the building and it will be readily understood that this cost is affected much more by the relative location of the building to the water supply and by the character of work required than by the actual size of the plant.

Similarly the electrical switching equipment costs depend much more on the extent and the scope of the electrical distributing system than upon the actual capacity of the plant. Again the largest item of the "Service Equipment" costs, namely that of coal handling depends upon the existing physical conditions much more than upon the capacity.

Some of these cost groups, however, can be reduced to other units than that of the kilowatt, and this permits a clearer understanding of their range.

The foundation costs, for instance, will run from $1.25 to $4.00 per sq. ft. of building plan area, depending on the character of the soil; the lower cost covering simple concrete footings on thoroughly good bearing soil, while the necessity for piling, waterproofing, excessive rock excavation, etc., will run this cost toward the higher limit. Then the plan area will vary from 0.8 to 1.5 sq. ft. for each kilowatt of capacity installed, depending upon the size of the units and upon their arrangement; the combined effect of these two cost ranges giving the range in price per kilowatt shown in the Table.

The building costs will vary from 8 to 12 cents per cu. ft. of overall building volume, according to the size of the building, the character of construction and the local price of building materials and labor. Depending again upon the size of the units and upon the efficiency used in arranging them, there will be required from 50 to 100 cu. ft. of volume per kilowatt of capacity. The combined effect is to make the building costs range from $4.00 to $12.00 per kilowatt.

In boiler room equipment the cost of materials and labor will generally be between $30 and $40 per nominal boiler horse power, and generally there will be installed between 0.4 and 0.6 boiler horse-power per kilowatt of capacity, resulting in the cost range shown in the Table.

Real Estate—The actual cost of real estate makes practically no difference in design in the very large majority of cases; for, as a general proposition, it may be said that if sufficient room is allowed around the apparatus for its proper operation and maintenance, no material benefit can be obtained by spreading the apparatus over more territory.

On the other hand, the location with reference to fuel and water supply and the physical condition of the property do very materially affect the cost, much more so indeed than any other one factor, except possibly the proportioning and arrangement of the apparatus. It is practically essential for any power plant of moderate or large size that the property have rail connections for the delivery of coal. It is also essential that there be an ample supply of condensing water, though cooling towers may be used with increased first cost and decreased economy. In the consideration of alternative sites, the cost of the "Yard Work" may have an important bearing.

Rarely indeed, is there a case where the site of a power plant is selected with regard only to the cost of land. If the power plant is attached to an industrial or manufacturing establishment, the site is located with regard to the handling of the raw material and the finished product. In the case of a central plant for light or traction, the power plant site is generally a selection between one or two available sites, and ofttimes is of commercial necessity fixed on a site long predetermined. Consequently, nearly every plant starts with a location which is not quite ideal.

Foundations—The condensing apparatus can only be placed a definite height above the extreme lowest level of the condensing water supply. This alone determines the basement floor level and, if in flood stages the water rises sufficiently to endanger apparatus at this level, more or less expensive costs are involved in the proper protection of the apparatus.

The bearing value of the soil largely affects the cost, as the necessity for piling under all foundations or the necessity for large rock excavation instead of good bearing soil at suitable level, will increase the cost two or three dollars per kilowatt.

Building.—The cost of the building is dependant upon the character of the structure which it is desirable to erect to be in keeping with the location and with other property of the operating company; but this cost depends much more on the efficiency in design and the proper arrangement and spacing of the apparatus.

With a fortunate size and arrangement of apparatus only 50 cu. ft. of building volume may be required per kilowatt, while with a disadvantageous size of apparatus and with less regard being paid to an economical arrangement as much as 100 cu. ft. often results.

Boiler Room Equipment—The range in the cost of the boiler room equipment is large, but as this item is of especial interest owing to its application in all types of steam plants, it will be the subject of more detail consideration later.

Turbine Room Equipment—The cost of the turbine room equipment depends mostly upon the size and the speed of the main generating units. Naturally, the higher the speeds the less the first cost of the aparatus. Units of 2000 kilowatts and less are now considered practicable with speeds of 3600 r. p. m., whereas the larger sizes run at 1500 or 1800 r. p. m.

Another factor affecting the costs of the turbine room equipment is the type of condenser selected. Condensers can be divided into two classes, first the surface condenser in which the condensing water does not come in contact with the condensed steam; and second the mixing condenser in which the condensing water and the products of condensation mingle.

As a surface condenser installation will cost from $1.00 to $3.00 a kilowatt more than the mixing type, the warrant for it must be thoroughly established. The selection between these two types of condensers depends upon whether or not the supply of condensing water is suitable for feed-water, as if it is suitable, there is no good reason for the surface type. If the condensing water supply is not suitable for feed-water, it is then a question of whether or not the surface condenser saves enough in the cost of feed-water to warrant its greater first cost. As a very general statement, if the cost of feed-water does noe exced six cents per 1000 gallons; and if the average load on the plant does not exceed one-half the maximum load, then surface condensers are not warranted.

Formerly with reciprocating engines, it was possible to decrease the first cost of a station when its fuel economy was not essential or particularly when used only as a standby plant, by omitting the

condensing apparatus. A steam turbine, however, takes about 50 to 70 percent more steam when running non-condensing than condensing, and the first cost of providing the extra boiler capacity to run the unit non-condensing is generally much greater than the cost of the condenser with the necessary flumes for supply and discharge of cooling water. This results in the peculiar condition that a non-condensing turbine plant not only will cost more to operate, but will actually have an equal or greater first cost: In other words, a non-condensing station is no longer commercially feasible, except, of course, where there is a large requirement of exhaust steam for heating.

Electrical Switching Equipment—The cost of electrical switching equipment does not necessarily vary proportionately with the size of the plant. It depends more directly upon the character of the service in which the electric current is used.

Service Equipment—In the service equipment the item of coal handling is the largest variable factor affecting the cost. If the plant is so close to the mines that a reasonably continuous supply of fuel can be relied upon, no large outside storage of coal may be necessary, and the supply generally provided for in an inside bunker, may suitably serve as a fly-wheel on the coal supply to the boilers. If the plant is at a considerale distance from the mines, more or less outside storage is desirable.

Mechanical handling devices are a distinct economy in a boiler plant of moderate or large size.

Starting Up and General Charges—The items of starting up and the general charges as shown in the Table hardly need any explanation except possibly to say that the item of starting up is often overlooked during the initial stages of the project, but is usually found when the final costs are added up.

A part of the foregoing items of variable cost in a power plant are determined as soon as the site of the plant is located; others are determined as soon as the load requirements are known, but a large number remain which are dependent upon the experience of the designer and his ability to formulate correctly and judge wisely between the equations of economy on the one hand and of first cost on the other.

Considering now in detail the question of boiler room equipment, Table II shows a probable high and low range of costs for this group of apparatus.

TABLE II—BOILER ROOM EQUIPMENT COSTS PER RATED BOILER HORSE-POWER; USING COAL FOR FUEL.

	DOLLARS PER HP	
	High	Low
Boilers exclusive of masonry setting	$11.00	$ 8.00
Superheaters	3.00	0
Stokers	5.50	3.00
Masonry settings for boilers	3.50	2.00
Flues	1.50	0.75
Stacks	4.00	2.00
Economizers	4.00	0
Mechanical Draft	3.00	0
Feed-Pumps	1.50	0.50
Feed-Heaters	1.00	0.40
All Piping and Pipe Covering	10.00	6.00
Coal Chutes and Ash Hoppers	1.25	0
Various, such as Indicating and Recording Devices Damper Regulator, Ladders and Runways, Painting, etc., etc.	1.00	0.50
Totals	$50.25	$23.15

Note—The above costs are for labor and material only. They do not include any "General Charges" such as Engineering or Supervision. The piping item includes all piping in the entire plant except condenser water piping.

The unit costs in Table II are related to rated boiler horse-power instead of the kilowatt as used in Table I, as these costs vary almost directly with the rating of the boilers. With a given cost per horse-power for this boiler room group, the cost per kilowatt will vary according to the proportioning of the boiler capacity to the generator capacity. This proportion is the most important single question in power station design that is subject only to the judgment of the designing engineer.

Considering the boilers themselves, there seems to be a decided tendency to use as large units as have been shown to be commercially satisfactory. This has practically resulted from the development of the steam turbine in large units.

There is every incentive from the standpoint of first cost to reduce the number of boilers to the minimum that will meet operating requirements, and therefore to make each boiler unit as large as practicable. This is done at a slight gain of economy, although first cost and not economy is the principal motive. Boiler units of about 600 horse-power each are common practice. Much larger boilers have been installed in a few cases, and the results to date are very promising.

In addition to using larger units, there is also a decided tendency to make a given amount of boiler surface develop more power. Many years ago it was defined that 10 sq. ft. of heating surface should constitute one horse-power in the rating of a boiler. With the gradual development of mechanical stokers and our greater knowledge of the laws governing the efficient combustion of coal, it is quite practicable to obtain one and a half, or even two horse-power from this same surface. In other

words, it is now customary to demand from boilers at least 150 percent of their rating; and frequently 200 percent.

As the boiler plant must be large enough to supply the maximum demand for steam, it will be seen that if we plan to work the boilers 200 percent of their rating at such times of maximum demand, we have practically cut in half the boiler group costs compared with former conditions.

The use of superheat ranging from 100 to 150 degrees, F. will improve the overall fuel efficiency of the plant from five to seven percent; and superheaters will generally result in an overall economy, even with coal as low as $1.50 per ton.

Economizers have two uses: economy of heat, and heat storage. In general, it may be stated roughly that with 50 percent annual load factor and coal costing $3.00 or more per ton, the saving in heat with the economizers, is enough to more than cover their fixed charges and maintenance. These conditions may vary 20 percent and the economizers still show an annual saving. The advantage of heat storage often justifies their use irrespective of the price of fuel. With a rapidly fluctuating load, the economizers aid the boilers in meeting sudden demands.

With the increased boiler pressures and superheat, and particularly with turbines taking steam continuously instead of intermittently, as with the reciprocating engines there has naturally followed a decrease in pipe sizes. Whereas, formerly an eight inch pipe would be used on a 500 hp boiler running not much over rating, a six inch pipe is now used on a 600 hp boiler and 1200 hp taken through it.

An important feature of steam piping is the pipe covering. Frequently the active competition between manufacturers leads to the use of inadequate covering. It pays to provide a good covering, well protected and so put together that it may be removed and replaced at small cost where necessary for repairs and adjustment of pipe joints and valves.

Under the heading of indicating and recording devices may be classed draft gauges, recording thermometers, gas sampling and testing apparatus, coal and water weighing devices, etc. These are not refinements. Their combined cost is almost negligible in the total cost of the plant. They are necessary to enable the superintendent to know just what is being done, and if accompanied by intelligent supervision, will, in any large boiler plant, save their cost many times regardless of the price of coal.

Table III has been prepared to indicate the range of common practice in coal consumption. Pittsburgh coal of 14 000 B.t.u's per pound is assumed for both cases. The annual average boiler and furnace efficiency will range from 50 to 70 percent, depending on the nature of the load, the suitability of the station design to this load, and the efficiency of the operating force. Therefore, for each pound of coal burned, the B.t.u's made effective in the steam. range from 7 000 to 9 800.

TABLE III—SUMMARY OF OPERATING RESULTS

		Range of Common Practice	
British thermal units per pound of fuel (assumed)	14 000		
Average yearly overall boiler and furnace efficiency %	50		70
Effective British thermal units per pound of fuel	7 000		9 800
Boiler pressure, pounds per square inch, gauge	125		190
Superheat, degrees Fahrenheit	0		125
Average feed-water temperature, degrees Fahrenheit	120		200
British thermal units per pound of steam (approximate)	1 100		1 100
Pounds of water evaporated per pound of fuel, actual	6.36		8.91
Pounds of fuel per standard boiler hp (33 305 B. t. u's.)	4.76		3.40
Average overall station water rate per kw	30		20
Pounds of coal per kw generated	4.72		2.25
British thermal units in coal per kw generated	66 000		31 500
Thermal efficiency of station, percent	5.2		10.8

Considering next the condition of the water and steam, the boiler pressure may be anything between 125 and 190 lb. In many cases no superheat is used, and in a steam turbine station where the conditions warrant it 125 degrees of superheat may be used. The temperature of the feed-water entering the boiler ordinarily varies between 120 and 200 deg. F. These condition of boiler pressure, superheat and feed-water temperatures may vary in an actual station more than the limits here shown; but the interesting thing is that the combination assumed for the two extremes result in the same number of B.t.u's per pound of steam. The explanation for this lies in the relative temperatures of the feed-water. The additional heat necessary to bring the temperatures of the feed-water of the one case up to that of the other, is enough to raise the steam pressure in the second case to 65 lb. above the first and to superheat the steam 125 deg. The steam in the second case will do ten percent more useful work than the steam in the first case. The importance of proper feed-water heating is apparent.

The combination of the figures in the third line and the seventh line results in those of the eighth line, so that the pounds of water evaporated per pound of fuel varies between 6.36 and 8.91.

Experience has shown that the average annual water rate of such stations, including the main units and all auxiliaries, varies between 30 and 20 lb. per kw.-hr. These figures divided by the rate

of evaporation, give the figures in the next line for pounds of coal per kilowatt-hour generated. These figures in turn multiplied by 14 000, give the B.t.u's in the fuel per kilowatt-hour generated, these being average figures for the entire year. A kilowatt-hour is theoretically equivalent to 3 420 B.t.u's. Therefore, the annual thermal efficiency of the station may vary between 5.2 and 10.8 per-cent. In other words, one station may require more than twice the coal per kilowatt hour per annum as another, even though both are condensing stations operated under conditions within the range of common practice.

Better overall results than the best here shown have been obtained for months at a time, if not years, but these have been cases of particularly large stations or exceptionally good load factors, and it it is not often the combination of conditions permits present day apparatus to exceed the high figure here shown.

On the other hand, many power plants do not get even as good results as the lowest in the Table. In many cases this is logically due to the small size of the plant or the character of the load, but in some cases it is due to improper design, and in many cases the poor results are due to lack of supervision and knowledge on the part of the operating force.

SUMMARY

In conclusion, therefore, the principal points which we wish to make are:—

First—A conventional power station design generally adaptable to a given class of service, is not practicable.

Second—Geographical location, in itself, should have no bearing on the design of a power station.

Third—The location with reference to fuel and water supply and the physical condition of the property, however, have a very important bearing on the cost.

Fourth—The cost of real estate in a large majority of cases has little to do with the design of a power plant. There is small difference between the area that will give sufficient clearances, and the minimum on which the apparatus could be placed. As between two possible sites the costs to be equated against real estate are mostly in the intake and discharge flumes and the coal handling facilities outside the power house.

Fifth—Ornamentation of a power station building to suit local conditions need not add greatly to the cost.

DIRECT-CURRENT ELEVATOR CONTROLLERS

W. H. PATTERSON

ELEVATOR controllers must fulfill the most exacting service requirements. The acceleration of elevator motors should be smooth, uniform and as rapid as is consistent with safety and economical operation. Stops should be made quickly and without shock or jar; and the car "inched," or its direction abruptly reversed, without damage to any part of the apparatus.

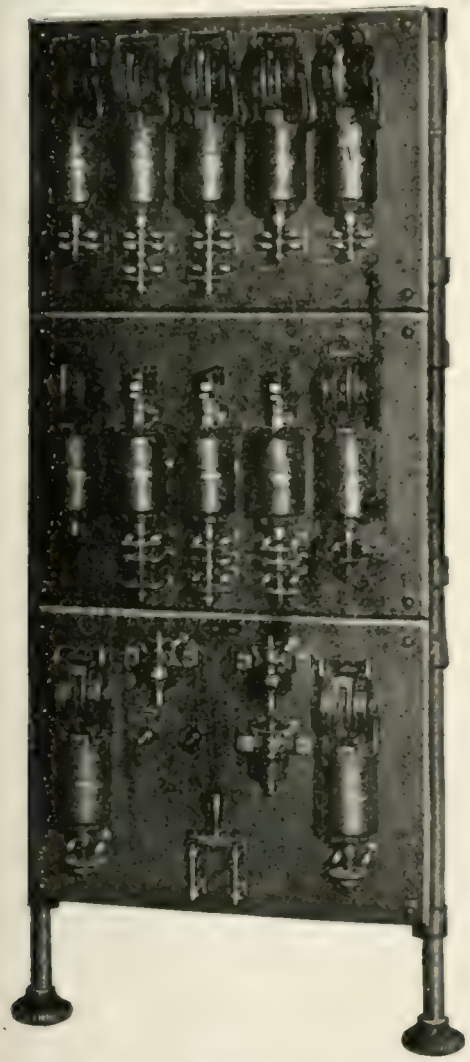


FIG. 1—FULL MAGNET, DIRECT-CURRENT ELEVATOR CONTROLLER

High speed passenger elevators running from about 200 to 600 feet per minute are practically always installed with full magnet controllers and car switches. A common type of such a controller and car switch are shown in Figs. 1 and 2. This type of controller is also used on heavy duty high speed freight elevators running up to about 200 feet per minute. The operation of these controllers with a compound-wound commutating pole elevator motor is as follows: In starting, the switch handle is usually moved from *off* to the *full on* position. The switches then operate automatically to start the motor and accelerate it promptly and smoothly to full speed. There is no disagreeable jerking or unnecessary stress on any of the mechanism.

The operation of the switches causes the following conditions, shown by the diagram and table, Fig. 3, while starting: (a) Switches *3*, *5*, *6*, *11* and *12* close and the motor starts with full field strength and with resistance in the armature circuit; after the motor has started, switch *1* closes; (b) switch *1* opens and the armature resistance is cut out in three steps by switches *7*, *8* and *9*, as the speed increases; (c) the series field is short-circuited by switch *10* and a resistance is cut into the shunt field circuit by the

opening of switch *11*. The series turns on the field have the effect of smoothing out the peaks in the current curve while the resistance is being cut out, and when these field turns are short-circuited they prevent sudden change of field magnetism so that the speed continues to accelerate smoothly when the shunt field resistance is inserted in a single step. The switch handle can be held on the second point if desired, giving the second of the foregoing conditions and an elevator speed about one-half maximum.

In stopping, the handle can be brought back to the second point, giving half speed, and then to the first point, giving the slow-down speed. The usual practice is to return the handle promptly to the first point, thus giving the motor full field strength, and inserting resistance both in series and in shunt with the armature. This condition gives the special slow-down speed, less than one-fourth full speed. Moving the handle to the off position causes all control switches to open and other switches to close and apply dynamic breaking, bringing the car easily and accurately to rest.

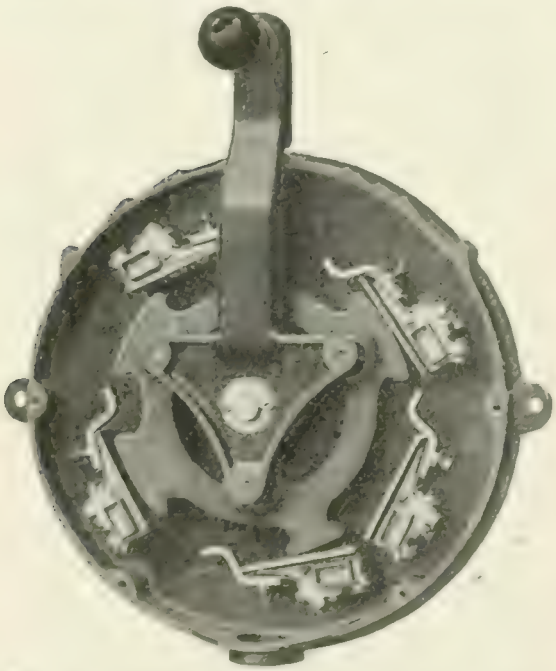


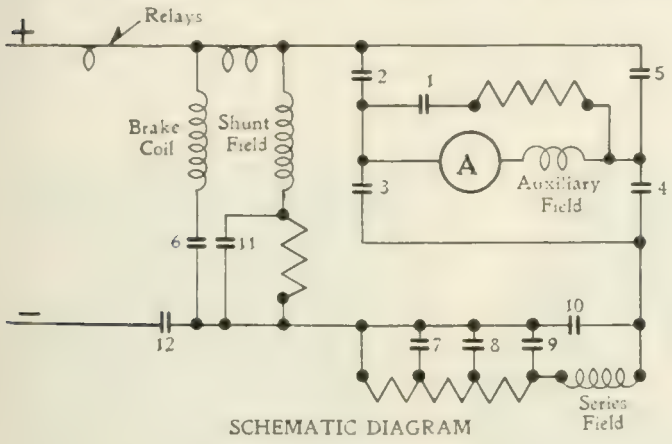
FIG. 2—THREE POINT CAR SWITCH WITH COVER REMOVED

An over-load re-set circuit breaker is operated by a series overload relay; it is re-set by opening and closing the emergency car switch. Tryout push button switches are provided on the control panel so that the elevator can be operated from the controller panel, if desired.

This conroller is practically fool-proof, and the operator cannot injure the motor or elevator by careless manipulation of the car switch. If he throws the car switch from the *up* to *down* position, or vice versa, the motor comes to rest, and the operator must bring the handle back to the off position before he can start the car in either direction, so that there is no possibility of throwing excessive stresses on the mechanism by sudden reversals. The circuit-breakers protect the motors from injury by heavy overloads, short-circuits, etc.

If the power supply fails, all switches open and the car comes

to rest. In such a case the operator ordinarily releases the car switch handle, which returns automatically to the off position. If he does not release it, and the power comes on again, the magnet switches close in the regular sequence, so that the car starts and accelerates smoothly in the regular manner; failure and subsequent return of power cannot injure the elevator mechanism or motor.



SCHEMATIC DIAGRAM

Sw	Run Up			Off			Run Down			
	III	II	I	Brake	O	Brake	I	II	III	
1			o	o o o		o o o		o		
2							o o o o o o o			
3	o o o o o o o									
4							o o o o o o o			
5	o o o o o o o									
6	o o o o o o o			o o		o o	o o o o o o o			
7	o o o o o						o o o o o			
8	o o o o			o o		o o	o o o o			
9	o o o			o		o	o o o			
10	o o			o		o	o o			
11	o o o o o o o			o o o		o o o	o o o o o o			
12	o o o o o o o			o o o o		o o o o	o o o o o o o			

SEQUENCE OF SWITCHES

FIG. 3—DIAGRAM SHOWING MAIN CONNECTIONS AND SEQUENCE OF OPERATION OF SWITCHES FOR FULL MAGNET ELEVATOR CONTROL

The operation of switches 8, 9 and 10 during dynamic braking has no effect so far as main contacts are concerned. The interlocking secondary contacts, not shown, serve to insure suitable connections for dynamic braking, and to prevent the setting of the friction brake, during normal operation, until the car has nearly stopped.

Modified forms of the above controller, eliminating some of the refinements, are used for slower speed passenger elevators, running up to about two hundred feet per minute. Instead of three points the controller has only two, full running and slow down. For freight elevators running up to a maximum speed of one hundred and fifty feet per minute this type of control is also used. The operation is the same except that a single speed motor is used instead of a two speed motor as in first case. For slower speed freight elevators, running up to maximum speeds of one hundred feet per minute, a further modification of the above controller is made, this type being single speed without dynamic brake, as at these slow speeds dynamic braking is not required in order to make easy and accurate stops.

The following accessories are generally used with all of the above controllers.

A machine limit switch is a drum switch that is driven by the elevator winding machine and stops the car at either limit of travel by opening the circuit of the magnet switches. The car can then be started in the reverse direction only. The switch is opened by a traveling nut and closed by a centering weight.

The hatchway limit switch is a single pole, double break snap switch with a long operating arm. One of these switches is installed at the top and one at the bottom of the elevator shaft. When the limit of travel is reached in either direction a cam on the car depresses the switch arm, opens the switch and stops the car.

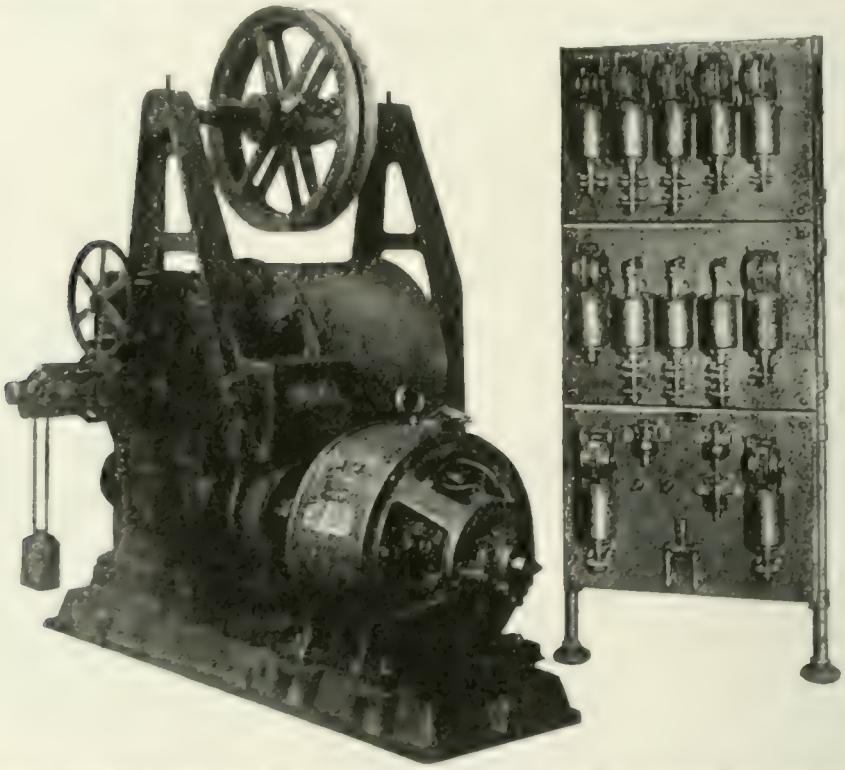


FIG. 4.—TWENTY-FIVE HORSE-POWER ELEVATOR WINDING MACHINE WITH DIRECT-CURRENT COMMUTATING POLE ELEVATOR MOTOR AND FULL MAGNET CONTROLLER

The car can then be started in the reverse direction only. When the pressure is removed from the switch arm, the switch closes automatically by the action of the spring.

The slack cable switch is an automatically operated master switch that stops the motor in case the rope slackens from any cause, such as the breaking of the cable or the catching of the car. The switch is mounted on one side of the winding drum and a little below it, and is operated by means of two bars that extend across the drum. When the rope slackens it presses against the cross bar and trips the switch, thus opening the control circuit, releasing the magnet switches and stopping the motor and the car.

The switch cannot be re-set until the cable has been replaced on the drum; inspection and necessary repairs are thereby assured.

When it is not desired to use the more expensive full magnet car switch control for freight and passenger elevators of moderate and slow speeds, a semi-magnet controller, Fig. 5, operated by a hand rope or lever in the car, is commonly used. This controller consists of a slate panel, with magnet switches, a series relay, a line switch and fuses on the front, and the resistor and drum type reversing switch in the rear. The reversing switch is generally connected to a shaft on which is a flanged pulley carrying the operating rope. The reversing switch does not open the main circuits, but merely arranges the connections and controls the magnet switches. The motor circuit is always opened by a magnet switch provided with blow-out coils.

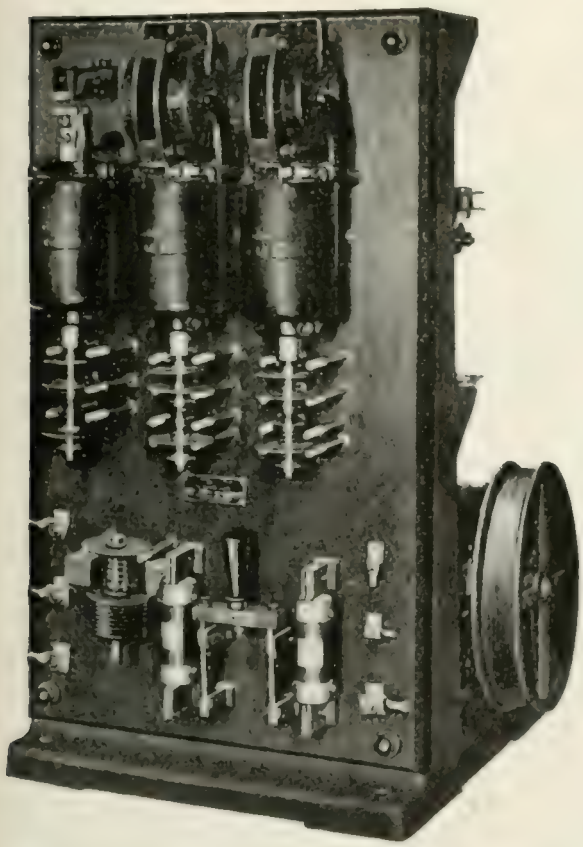


FIG. 5—SEMI-MAGNETIC DIRECT-CURRENT ELEVATOR CONTROLLER

The operation of these controllers is as follows: Turning the drum reverse switch by moving the hand rope or lever in the elevator car arranges the motor connections for proper direction of rotation and then causes the magnet switches to close in proper order. The rate of closing these switches is controlled by a series relay which thus prevents excessive current being taken by the motor. The closing of the switch connects the motor to the line and brings it to full speed by cutting out first the armature resistance and then the series field. When the drum reverse switch is moved to the off position, the magnet switches open, disconnecting both sides of the motor from the line. Either electric or mechanically operated brakes may be used with this type of controller. Machine limit switch, hatchway limit switches and slack cable switches may also be provided with controllers of this type.

OUTDOOR TYPE TRANSFORMERS

C. S. LAWSON

THE great number and length of high voltage transmission lines in America has led to the development of transformers and auxiliary apparatus for outdoor service, by means of which light and power may be supplied to communities or factories located near high voltage circuits, particularly where the amount of power required does not justify the expense of a sub-station building. The progressive farmer has begun to realize the advantage of electric light and electric drive for his farm tools, and becomes a ready user of electric power when it is available. The outdoor transformer, however, is not limited to supplying the small amounts of power required by the farmer or the small community.

For temporary or semi-portable sub-station service the outdoor transformer is invaluable. As an instance of such application may be mentioned the 33 000 volt outdoor transformers supplying power to motors operating shovels, dredges and drills in the construction of the Los Angeles Aqueduct.

Experience has shown that outdoor apparatus can be built to give service as reliable as that of indoor apparatus, and the question as to which type should be used, regardless of the capacity and voltage involved, finally reduces to one of costs; accordingly each case must be worked out on its own merits. Just as the lighting company in a city supplies light and power to the residents of the city, the electric-transmission company may serve cities, towns and villages throughout a large territory, and no user of power is too insignificant to be regarded. For comparatively small amounts of power, where a single transformer or bank of transformers would be installed, the outdoor transformer with a minimum of auxiliary apparatus is especially adapted and is in fact the logical solution if there is no other apparatus which must be housed.

The idea of the outdoor transformer is obviously not new. The first transformers built for commercial service were the ordinary lighting transformers on outdoor circuits of 2 300 volts and below, and were designed for mounting on poles. The primary voltage of lighting or pole type transformers has been increased from time to time until there are now on the market standard lines of single and three-phase transformers for voltages up to and including 16 500 volts and capacities of approximately 100 k.v.a. All

of these transformers are of the oil-insulated and self-cooled type and are designed for pole mounting.

Transformers above 100 k.v.a. capacity, generally spoken of as "power" transformers, are too large for pole mounting, and may be mounted on raised platforms, concrete floors or skids. Power transformers for outdoor service may be built for any voltage and capacity for which indoor transformers may be built. Since one of the factors favoring the installation of outdoor transformers is the small amount of attention which they are ordinarily destined to receive after being put in service, and since transformers of the water-cooled type require more attention than self-cooled units, there is very little demand at present for outdoor water-cooled transformers. In a large percentage of cases the outdoor transformers will be installed in places where there is no convenient supply of water for cooling purposes. However, the water-cooled transformer for outdoor service is not unheard of, and there may be conditions for which such transformers only would be suitable. The advent of the tubular type tank for oil insulated, self-cooled transformers has increased the capacity for which these types of units may be built, until the size is now limited only by railroad clearances in shipping. While the self-cooled transformer in a tubular tank costs more than a water-cooled transformer, it is frequently found that the self-cooled unit offers the cheaper proposi-



FIG. 1—OUTDOOR TYPE OIL-INSULATED, SELF-COOLING TRANSFORMER
15 k.v.a., 33 000 to 23 000 volts.

tion when the cost of cooling water is taken into consideration.

Outdoor transformers differ from the indoor types in that they must have cases with covers and manhole doors having a considerable overhang and bolted down on gaskets. Outlet leads are sealed into the bushings with weather-proof compound and the bushings either sealed directly into the case with a suitable compound or into flanges which are bolted down on weather-proof gaskets.

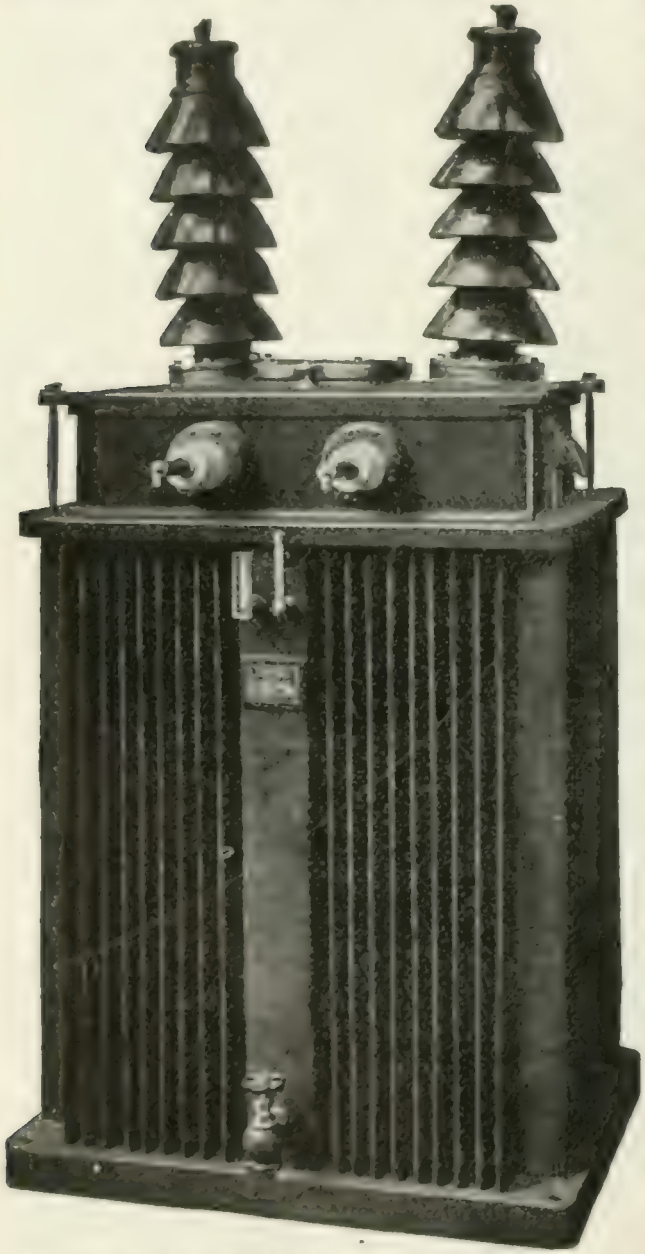


FIG. 2—OUTDOOR TYPE OIL-INSULATED, SELF-COOLING TRANSFORMER

100 k.v.a., 30 700 to 7 200 volts. For star connection on 53 000 volt line.

The cases for small low voltage transformers are made of solid cast iron. For small capacity high voltage transformers the case is usually made of boiler iron with all seams welded. For larger sizes the "cast-in" type of case is used. This case has the wall, or housing, made of corrugated sheet steel with seams electrically welded and is cast into a base and top piece of cast iron, thus obtaining a strong and oil-tight joint. The cast-in type of tank is used for self-cooled transformers up to capacities of 500 to 1 000 k.v.a., depending on voltage and frequency. For larger capacities the cast iron tank becomes too large and expensive and the "tubular" type is used. The tubular tank is made of boiler iron with all seams welded and has one or more rows of boiler tubes on the outside, welded into the tank at top and bottom. The circulation of oil in the tank is up-

ward through the oil ducts in the transformer and downward through the tubes, where its heat is radiated to the surrounding air.

The question of the "breathing" of transformers and danger of condensation of moisture inside the tank is sometimes raised. If a transformer case is not perfectly air tight, the air and oil in the top of the tank expands as the transformer heats up and part of the air escapes through the openings; as the transformer cools, the reverse action takes place and new air is drawn into the tank. Under extreme conditions of weather there may be some condensation but the amount is so small as to be negligible. The almost total lack of break downs due to condensation in tanks is the strongest evidence of the insignificance of this feature of operation.



FIG. 3—OUTDOOR TYPE CONDENSER TERMINAL ON 1 000 K.V.A., 100 000 VOLT POWER TRANSFORMER WITH TUBULAR TYPE TANK

Terminals provided with porcelain bells.

The main problem in the design of outdoor transformers is in connection with the outlet bushings. They must be designed to stand all conditions of weather — rain, snow and sleet—and the accumulation of dirt, and it is these requirements which differentiate outdoor from indoor transformers. With transformers designed for pole mounting (limited to 16 500 volts) the problem of the outlet lead is best solved by making the top part of the case with overhanging pockets, into which the bushings and leads are placed projecting downward. The bushing, which is made in one piece, is sealed into the pocket and a cable lead sealed into the bushing with oil and moisture proof compound. With this arrangement the bushing is protected from mechanical injury, snow or foreign matter cannot accumulate on it, and a very cheap and serviceable outlet is obtained. Transformers in cast-in cases too

large for pole mounting may have the leads brought out either through the side of the top casting or through the cover if the voltage does not exceed 11 000 volts, and through the cover only if the voltage exceeds 11 000 volts. With a boiler iron or tubular case the general practice is to carry the leads out through the cover only.

For voltages above 16 500 volts, in order to obtain safe creepage distances, the outdoor outlet bushing is made up of two or more porcelain insulators cemented together. It is necessary to place this type of bushing in a vertical position so that it will shed water properly and it can therefore be located only on the cover of the transformer. The usual practice in building up these bushings is to use a plain porcelain bushing for the base such as is ordinarily used for indoor service, on top of which are cemented, one above another, enough petticoat insulators to obtain the safe creepage distance corresponding to the line voltage. The petticoats are of such shape that they telescope over one another. The

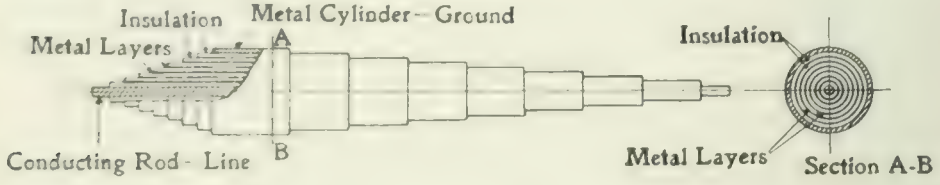


FIG. 4—CONDENSER TYPE TERMINAL

lead or conductor is carried up through the center and is covered with an insulating tube up to within two or three inches from the top. The insulating tube is cemented into the porcelains and they in turn are cemented together with weather proof compound This type of bushing may be used for voltages up to about 70 000 volts.

For voltages above 70 000 volts the outlet terminal described in the preceding paragraph becomes too bulky on account of the number of petticoats required, due to the unequal distribution of the static stress between points at line and ground potentials. One of the methods of overcoming this bulkiness is by the use of the condenser type of terminal. This terminal is made up of concentric layers of specially treated paper alternating with layers of tin foil, the layers being so proportioned in length and thickness that the capacity between any two adjacent layers is approximately the same. This construction results in a terminal with each succeeding layer shorter than the layer over which it is wound, as

shown in Fig. 4. The terminal is made weather-proof by cementing a porcelain petticoat at the end of each layer.

As with indoor transformers, in selecting outdoor transformers for service on three-phase lines, the question arises as to

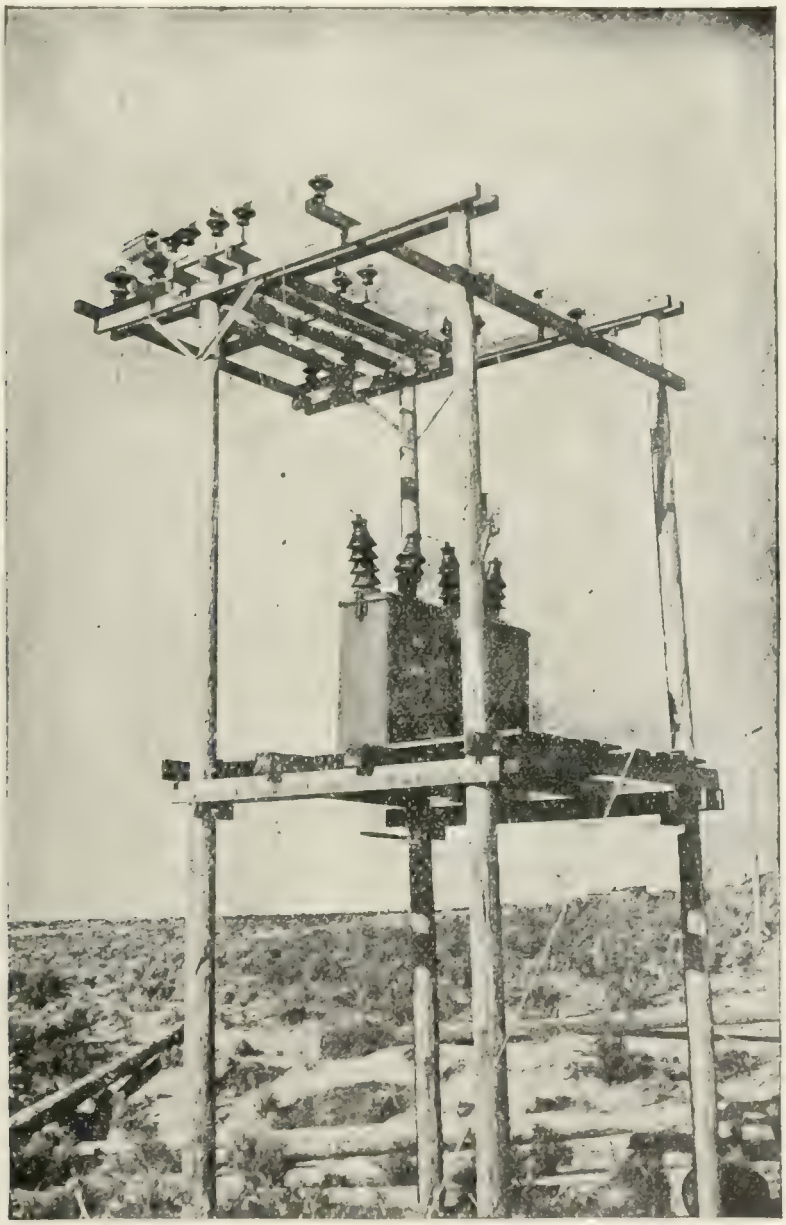


FIG. 5—INSTALLATION OF TWO OUTDOOR TYPE OIL-INSULATED, SELF-COOLED TRANSFORMERS ON THE LINES OF THE GREAT SHOSHONE & TWIN FALLS WATER POWER COMPANY

Capacity of each single-phase unit: 30 k.v.a., 60 cycles, 44 000 volts high-tension to 2 300 volts low-tension.

whether three-phase transformers or banks of single-phase units should be installed. With a three-phase transformer there will be three high-tension outlet leads through the case, while with a bank

of single-phase transformers there will be six high-tension outlet leads. With high voltage outdoor transformers this is a question well worth considering. The main advantages of the three-phase transformer are:—lower cost, smaller floor space, lighter weight and slightly higher efficiency. The main disadvantages are:—greater cost of spare units and greater derangement of service in case of break down. In the majority of cases where outdoor transformers are installed they will be used as distributing transformers or to serve a limited number of customers, in which case a spare unit would not ordinarily be installed and the derangement of service in case of breakdown would be local and accordingly not very serious.

It will be noted that the disadvantages of the three-phase transformer relate almost entirely to the failure of the apparatus. With the advance in the art of designing, building and treating transformers, however, the chances of failure are very small. Care is exercised in the winding of the coils, and each coil is thoroughly inspected and tested. For voltages above 11 000 the end turns are more heavily insulated. The coils are dried and treated with an oil proof varnish or compound before being assembled in the transformer. After being completely assembled the transformer is vacuum dried and immediately placed in oil. The transformer is shipped completely assembled in its own case in oil, so that there is no chance for it to absorb moisture after being dried, and there is no necessity for drying out at the point of installation.

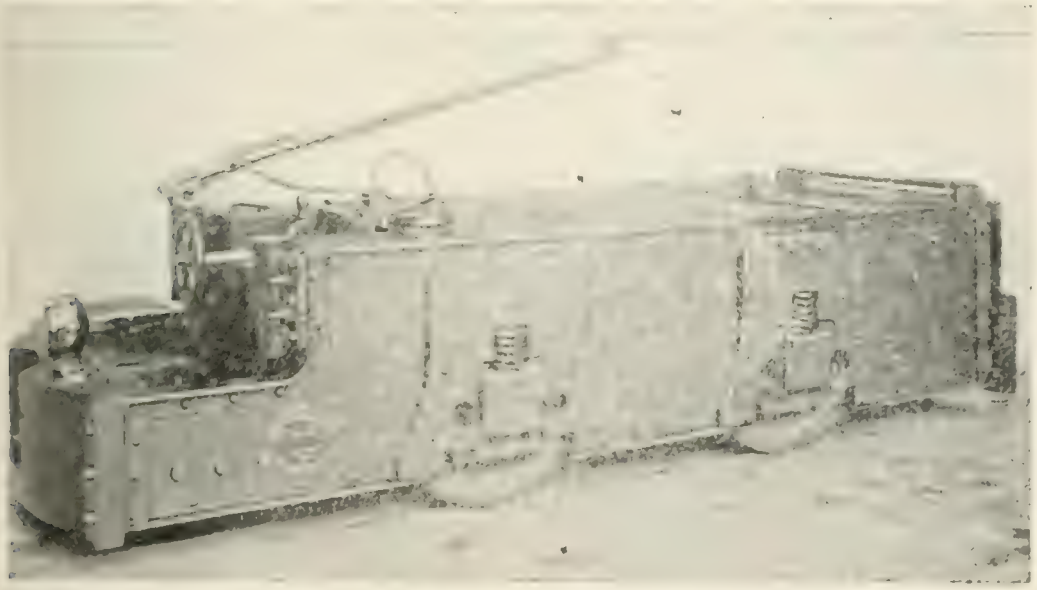
The advantages of outdoor over indoor installations are:—lower cost due to the omission of the housing for indoor apparatus; simpler construction; much less time required for installing, and less life and property hazard. The disadvantages are the absence of protection from weather when inspecting or repairing, and liability to molestation.

After considering the advantages of outdoor transformers and the satisfactory service they have rendered since the introduction of this type of transformer for commercial service, it would seem that for step-down transformers for general distribution, lighting and industrial service, in a temperate climate, the outdoor transformer should prove the more desirable. The high voltage outdoor transformer is a normal development to meet present conditions and should always be given due consideration in laying out a transmission system.

OPERATING FEATURES OF MINE LOCOMOTIVES

G. W. HAMILTON

ELECTRIC locomotives, in many instances, are not handled to the best advantage because in their selection sufficient attention has not been paid to the work which is to be done, the number of cars to be hauled, the grades and curves to be taken, and the relation of motor capacity to weight of locomotive. By carefully studying the local conditions and supplying equipment to correspond, it is frequently possible to secure from ten to twenty-five percent increase in hauling capacity over locomotives of the same tonnage less carefully selected or operated under less favorable circumstances. A locomotive hauling a trip



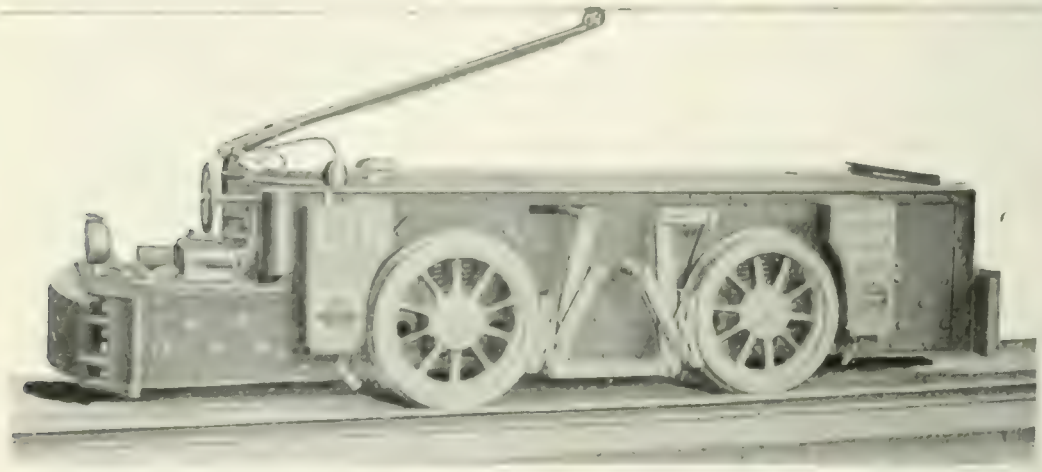
MAIN HAULAGE LOCOMOTIVE
Wheels inside of frame

over rough and unsteady track, with sharp curves and other unsuitable conditions, cannot produce the results that might otherwise be expected. It is of course a well known fact that what will suit in one mine may not serve so well in another, but there are features of development which those in charge should keep in view and gradually plan to accomplish.

The tendency today in most new shaft mines, with ample coal rights, is to hoist a large output as soon as possible after the shaft is down, and in older mines employing horses or mules for haulage to keep up or increase the output over the ever increasing distance. In the first case the workings should be developed to

suit mechanical haulage at an early date, while in the second preparations should be made to take the mules off the main entries and reduce the length of their runs to a minimum. As the success of electric locomotives for gathering or main haulage is frequently impaired by conditions below ground which should not exist, we briefly enumerate some of the main features producing these conditions.

In opening up the mine, plans should be made to keep the burden of the work of transportation on the main haul locomotives, and to this end the inside partings or side tracks should be kept as near as possible to the cross entries on the main road, or near the outside working rooms in the cross entries, so that the run for mules, or gathering locomotives, may be short and trips frequent,



MAIN HAULAGE LOCOMOTIVE
Wheels outside of frame

and their output greater and more reliable. It is well known that concentration of working places secures the greatest output, as time is not lost in hauling the coal but in running after it.

To aid this work the most important detail is good track. It is a poor investment to install 12 or 16 pound iron on the entries, and two by four inch lagging in the rooms to serve until locomotives are installed, as the saving in first cost is soon lost by the delays, damage to equipment and stock, reduction in output and dissatisfaction among the men caused by cars leaving the track, and the extra work this entails. With light iron, stub switches generally follow everywhere except at the bottom, and while they serve when horses or mules are used they must be replaced by latches to permit the use of locomotives. In other words it is necessary not only to relay the track and furnish

latches for all working rooms and turnouts, but if the change in weight of rail is marked, the ties must be relaid with the consequent work on the bottom. In an old mine the only way in which the output may be maintained, or increased, without increase in cost of production, is to haul large trips at regular and frequent intervals. To this end locomotives must be installed and to insure their success the track on which they will operate must be sufficiently heavy and well laid. When the track is laid, or relaid, it is good policy to locate it to one side of the entry, generally

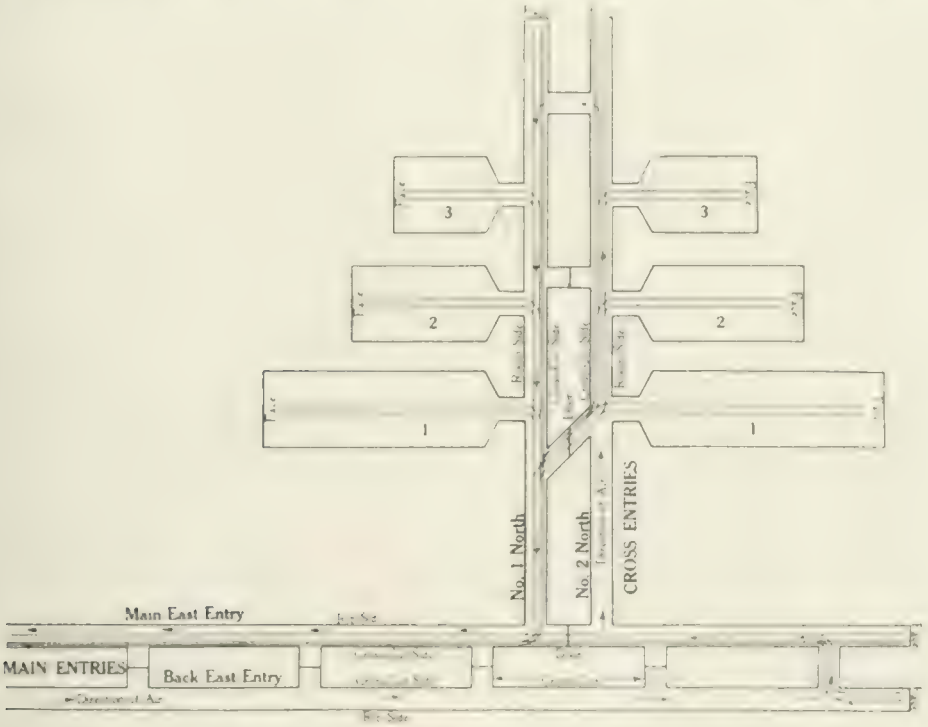


DIAGRAM OF A PORTION OF A TYPICAL ILLINOIS COAL MINE

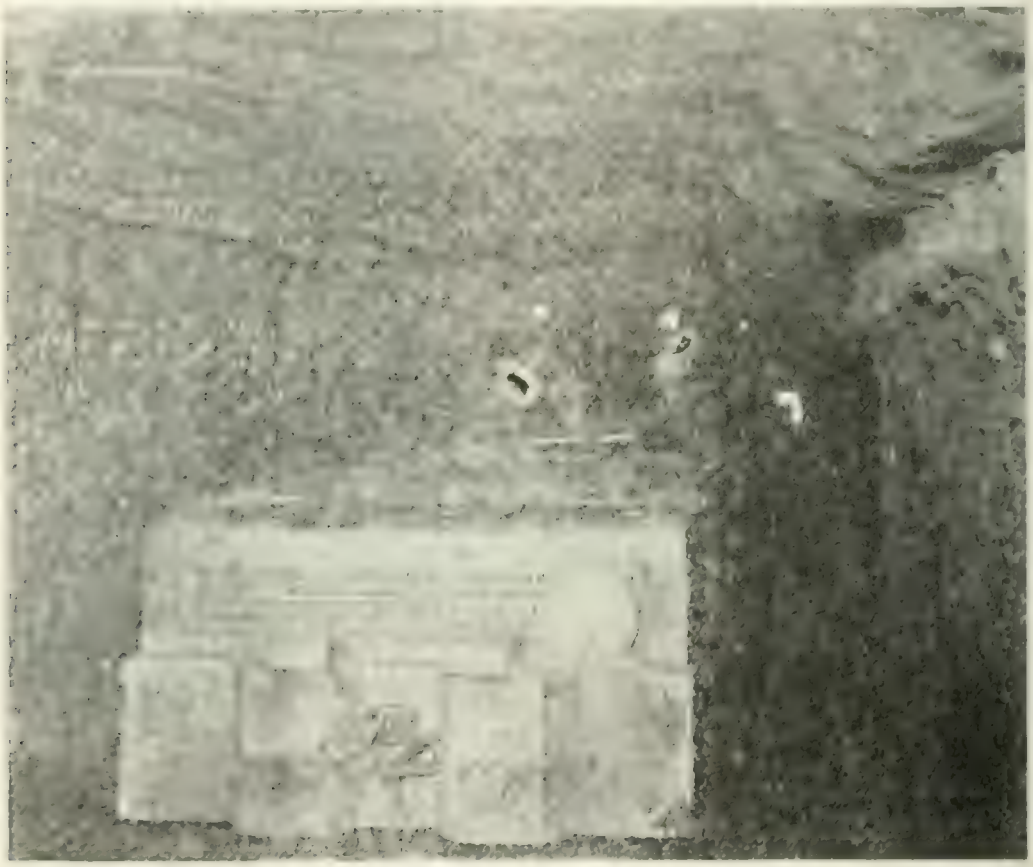
Working the rooms on both sides of the entries is customary only in mines where the strata are comparatively level. In the Pennsy'vania and West Virginia mines it is usual to work from one side of the entry only, in such a direction that the rooms will drain into the entry.

the crosscut side, as by so doing ample room is left on the rib, or room side, to permit those employed to pass the trip. This feature applies to all entries over eight feet in width, care being taken to leave about 18 inches between rail and near rib, on straight track, if conditions demand a small clearance.

If the main haul locomotives are to visit partings in the cross entries the curve from main into cross entry should be of at least 20 foot radius for track gauges of 30 inches and over, and the setting of the track on the crosscut side will help in the laying of these

curves not only from main into cross entry but from cross entry into rooms.

When planning the switch latch it is advisable to locate the point of the latch well outside of the stub point, or the inside switch point, if a double latch is used, so that when the locomotive strikes the switch point facing, it may be slewed over and so take the switch every time. Whenever practicable all switches should face out. If the entries are narrow the location of the partings



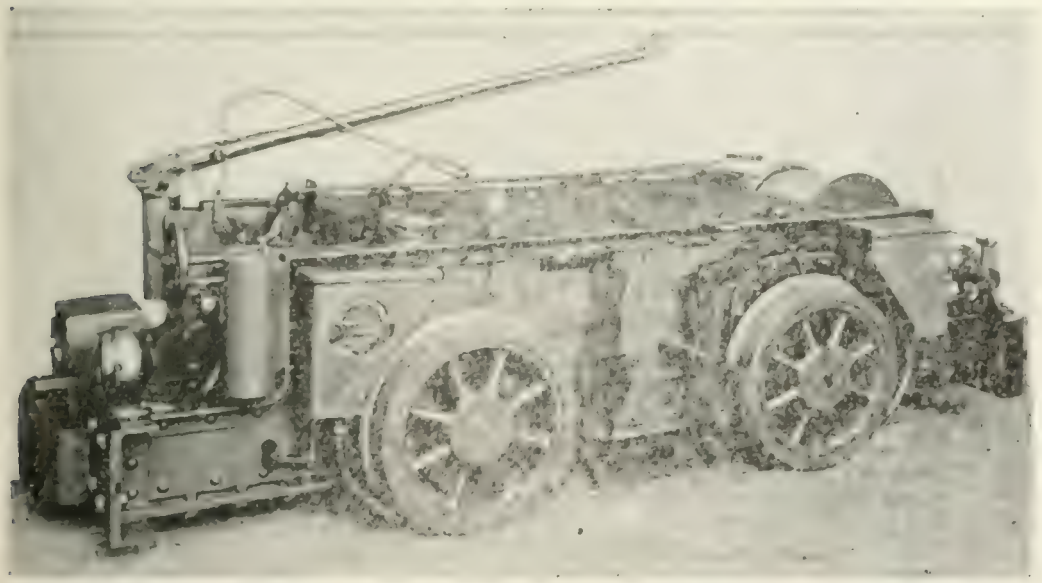
WIDE DOUBLE DOOROAVE IN MINE

Showing how the track is located at one side of the entry, and the trolley wire is located at one to endanger the men or mules.

should be planned so as to secure width and length, and it is good policy to make the main parting long enough to hold two loaded trips, so that should any delay occur between parting and shaft it will not delay those inside until time for two round trips has elapsed.

The trolley wire is best located well outside of the track, say six or eight inches, and on the crosscut side, so that workmen may travel on the ties, usually the best place, free from its obstruction. When so located on the cross entries men and mules do not have to pass under it in going in and out of the rooms, and in addition

to this the top is usually better close to this side. When located over the entry, as in passing from the main road into a cross entry, or into the back entry, it is well to protect the wire by means of an inverted trough of wood unless ample height prevails. Where trolley frogs are needed, they should be placed well inside of the track switch so that before the trolley wheel strikes the frog, the locomotive will be turning on the switch and cause the wheel to bear in the right direction. One advantage gained by having the trolley wire outside of the track is that the trolley pole must extend from the locomotive out and up to the wire, and in this position tends to follow the straight wire at all frogs, and



GATHERING LOCOMOTIVE WITH REEL FOR ELECTRIC CABLE

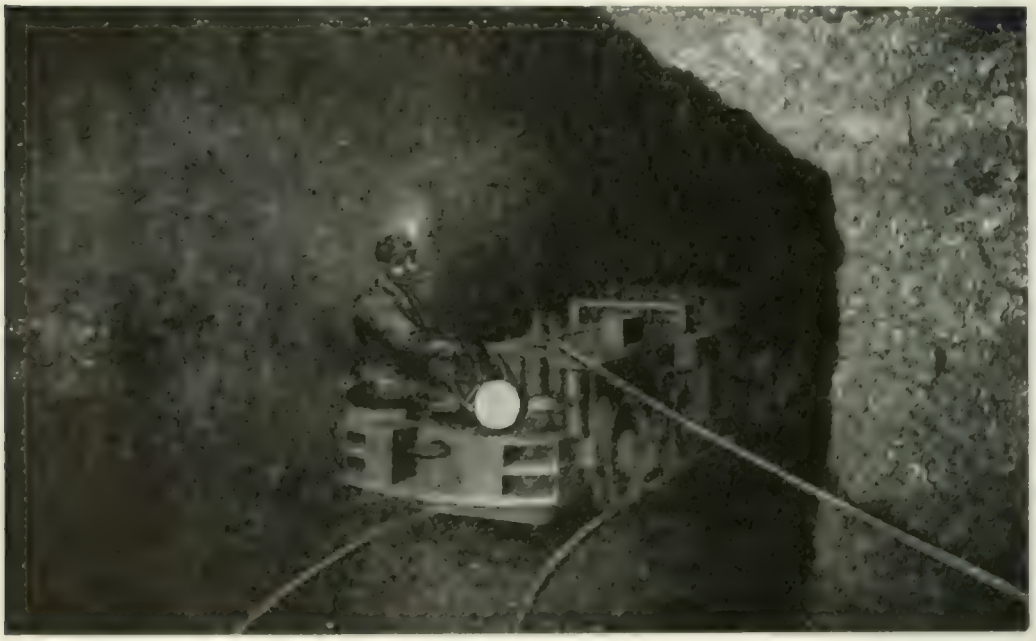
This type of locomotive runs into the rooms after the cars, securing power from the trolley wire in the cross entry through a reinforced insulated cable carried on the reel at the rear.

should it leave the wire, will jump toward the track and so clear the overhead construction.

If the track is to be re-laid and the trolley located, it will pay to study the conditions of service to determine present and future output, and so plan all details that the bulk of the work may be handled in the easiest and most economical manner. Good track insures good bonding, a very important part of the installation, which cannot be maintained without constant inspection if the rails are rising and falling as the load passes over them, or heaving and moving because of poor bottom.

Another important feature is the purchase of new mine cars or the overhauling of those in use. If the mine is a new one,

heavy and well built cars with simple but strong running gear should be secured, attention being given to the bumpers and couplings that good results may be obtained with long trips on curves, or when backing up. If the cars are old they should be thoroughly overhauled, bearing in mind that a locomotive hauling 30 to 40 cars per trip at 6 to 12 miles per hour is much more severe on the car equipment than a horse or mule handling from two to four cars at three to six miles per hour. To illustrate the value of good track and attention to rolling stock, we have known of mine cars of the same build and age which on test showed a resistance due to friction at one mine of 40 pounds per ton, and at another



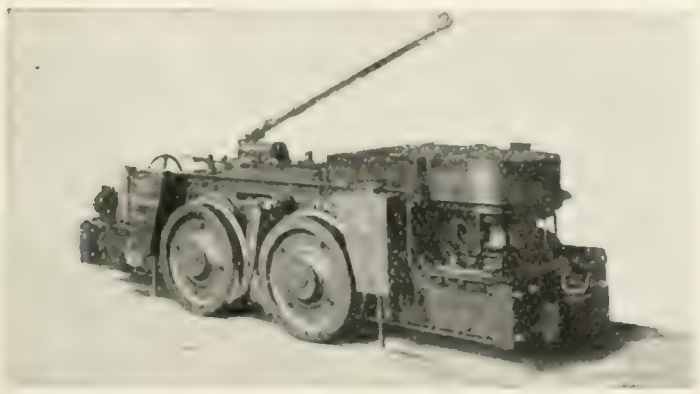
GATHERING LOCOMOTIVE RUNNING INTO A ROOM AFTER A CAR

of from 18 to 20 pounds. One can readily see what effect this would have on locomotives when installed to meet these conditions.

These few main features may appear of much less importance than long or heavy grades, but it is poorly laid or light track, with cars jumping off, hard running, slow speed, low voltage due to loose bonds, badly placed trolley wire with loss of current, burning of the trolley wire and trolley details, and trolley wheels jumping at frogs and uneven hangers, that delay the service, reduce the output and increase the cost continually. There are many locomotives in service which do not secure two-thirds of their capacity because of such conditions, and there are other locomotives which are badly handicapped because they were purchased by weight only, regardless of the equipment required. To some a 10 ton electric locomotive is much the same as a 10 ton

steam locomotive, that is, its pull is about one-fourth of its weight on the drivers when on level track, and as long as the cylinders are large enough, and the steam pressure high enough to obtain, through the intervening mechanism, a slipping of these drivers under all conditions, satisfactory operation is insured.

An electric locomotive should be constructed to meet the work required of it, and when it is known that 10 ton electric locomotives are equipped with motors ranging in capacity from 6 to 13



GATHERING LOCOMOTIVE WITH TRACTION REEL

Where grades are too steep for a gathering locomotive to go into a room after a car, this type of locomotive is anchored in the cross entry and a steel cable is drawn into the room and fastened to the car. This cable is then wound on the reel by means of a small motor, dragging the car up to the locomotive.

horse-power per ton and their operation guaranteed, the need for careful investigation should be apparent. It is therefore to the interest of all who contemplate the use of electric locomotives to have the conditions of service gone over on the ground by a representative of the manufacturer, if the data required cannot be otherwise obtained, so that, should a purchase follow, apparatus which will give the highest efficiency and economy will have been secured.

SINGLE-PHASE COMMUTATOR MOTORS

MOTORS WITH PREVENTIVE LEADS

R. E. HELLMUND and W. P. SMITH

IN the article on "Single-Phase Commutator Motors" in the February issue, it was shown that to operate a direct-current series commutator motor on alternating current certain changes are necessary and the design and construction tend toward certain definite characteristics which are inherent. A review of some of these features leads directly to a further discussion of certain design details in connection with motors of this type, especially with relation to the use of various arrangements of "preventive" or "resistance" leads in the armature winding.

The sparking caused by the current due to the transformer action of the main field flux on the coils short-circuited by the brushes and the iron loss due to the alternating nature of the flux are inherent difficulties which have to be overcome in order to secure successful operation of an alternating-current series commutator motor. The iron loss can be reduced by using a laminated field structure, as indicated before; the short-circuit current can be reduced by using a low main field value. But even using as low a value as is consistent with the rest of the motor design and construction, it is desirable to further reduce the sparking and burning due to this short-circuit current. It will be evident then, that if some means of further decreasing this short-circuit current without decreasing the field flux were introduced in the local circuit comprising a coil, two commutator bars and a brush, either more successful and satisfactory operation would be obtained, or for the same degree of satisfactory operation a stronger field flux could be used, with consequent increase of torque. Next to reducing the voltage, the most natural means of reducing current in a circuit is by inserting resistance in that circuit; hence, if some suitable resistance is used between the brushes and the coil short-circuited by them, the short-circuit current will be reduced. This resistance can easily be placed between the commutator bars and the armature coils, as indicated schematically in Fig. 1. The resistance or preventive leads, as thus connected, come into play only when a coil is being short-circuited by the brushes; they are in reality extensions of the commutator bars. Consequently, it will be seen that at any instant as the armature rotates, only the leads connected to the bars which are momentarily

in contact with the brushes carry the working current; at all other points around the armature the working current passes through the armature coils only.

The question of the advisability of using resistance leads to improve the commutation of a motor has been much discussed, due to the fact that there are inherent advantages and disadvantages in this scheme. At the same time, however, it appears from some discussions, that the function of resistance leads and certain of their effects upon the operation of the motor are not generally understood. In discussing this matter in detail, a number of well known facts will have to be repeated.

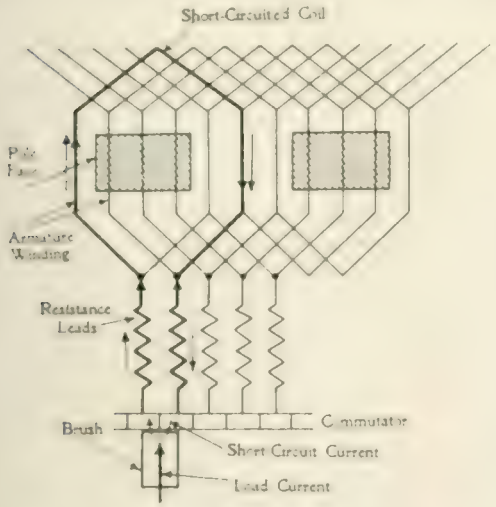


FIG. 1—SCHEMATIC DIAGRAM SHOWING ARMATURE COIL, WITH RESISTANCE LEADS, SHORT-CIRCUITED BY BRUSH

The main purpose of the resistance leads is to improve the commutation. In fulfilling this purpose they are superior to any other means, as they are effective in reducing the short-circuit currents under all conditions. They are equally effective for all motor speeds, and not only reduce the current caused by the fluctuation of the main field, but are also effective in reducing any other currents which may be induced in the short-circuited coil by higher harmonics or current surges caused by hunting phenomena and the like.

A second marked advantage of the resistance leads is that they reduce the losses in an alternating-current motor. It is especially in this connection that the effect of resistance leads is frequently misunderstood, as the word "resistance" naturally suggests additional losses. The ohmic losses in an alternating-current armature consist of two parts; first the losses due to working current, which are the same as in a direct-current machine, and second, the losses due to the short-circuit currents flowing in the circuits formed by each armature coil, as short-circuited, and the brushes, as shown in Fig. 1. It is evident that if the resistance of each coil and the brushes as short-circuited is very small the short-circuit current will be very large, and consequently the losses caused by the short-circuit currents will be very large. This is evident as these losses

are practically equal to the product of the short-circuit current times the short-circuit voltage, which latter is definitely fixed by the magnitude of the field flux. In other words, the total losses in the armature are large if the resistance of the short-circuited coil is low. If, however, a certain resistance be added between the short-circuited coils and the brushes, the current flowing will be reduced and with it the short-circuit losses, the field, and therefore the voltage being assumed to remain the same. While, at the same time, the losses due to the working current will be somewhat increased, it can be shown by a simple calculation, that by adding a certain value of resistance the reduction in the losses caused by the short-circuit current is greater than the increase in losses caused by the working current flowing in this resistance, and that a minimum value of total losses is obtained when the short-circuit current is approximately equal to the working current.* This is indicated by the curve in Fig. 2, which shows how the total losses in the short-circuited coil vary with the resistance of the leads. It will, therefore, be seen that the introduction of resistance leads of proper design actually means a reduction in the motor losses, and therefore, an increase in the motor output.

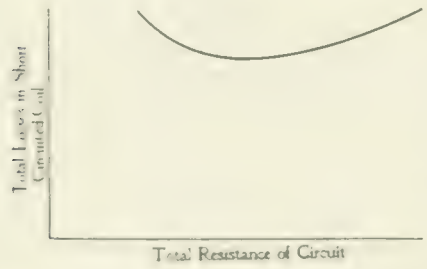


FIG. 2—CURVE SHOWING RELATION OF LOSSES IN SHORT-CIRCUITED ARMATURE TO TOTAL RESISTANCE IN CIRCUIT

The third advantage of the resistance leads is to be found in the improved starting conditions of the motor. This can be best explained by reference to the simple vector diagrams shown in Figs. 3, 4 and 5. For the purpose of demonstrating the point under consideration it will be fully permissible, for the sake of simplicity, to neglect the effect of the motor core losses and the magnetic leakage. Fig. 3 represents the conditions as they would exist without any short-circuit current losses. The vector F represents the main field flux whose phase is 90 degrees behind the impressed voltage of the field. The value of F is assumed to be constant in the three cases. Under the assumed condition of Fig. 3, viz., of no short-circuit current losses, the field flux is, of course, induced by the working current of the motor only, as field and armature are in series, and

*See book on "Alternating-Current Commutator Motors," by Dr. Ing. R. Goldschmidt, page 49.

is therefore in phase with this working current. The voltage drop caused by the ohmic resistance in the motor is in phase with the current and is represented by the vector Tr. The resultant of this vector and Ei, the inductive voltage of the field, is E, which represents the total impressed voltage required, since under starting conditions no rotational voltage is induced. The torque under these conditions is directly proportional to the field times the current, since the current and the field are in phase with each other.

Referring now to Fig. 4, which takes into account the effect of the short-circuit current, the voltage induced in the short-circuited coil lags 90 degrees behind the field flux F, and if, as previously assumed, the self-induction of the short-circuited coil is

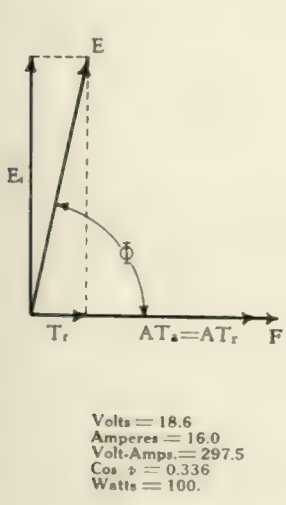


FIG. 3

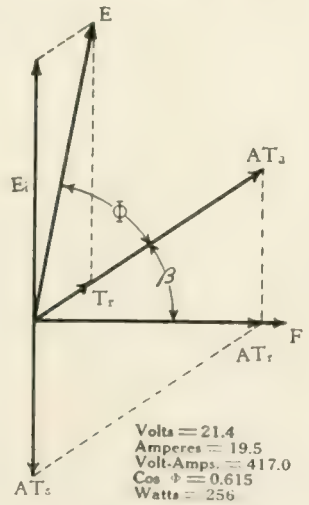


FIG. 4

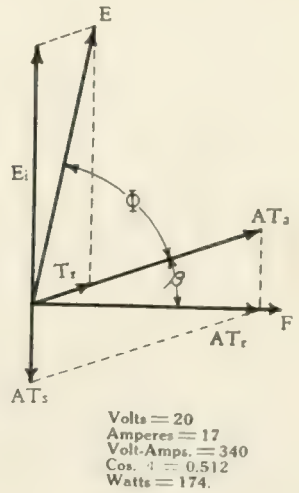


FIG. 5

VECTOR DIAGRAMS SHOWING EFFECT OF SHORT-CIRCUIT CURRENT ON POWER-FACTOR OF MOTOR

Fig 3; short-circuit currents neglected.
Fig. 4 shows the case of an armature without resistance leads.
Fig. 5 shows the case of an armature with resistance leads.

neglected, the current in the short-circuited coil will be in phase with its voltage. The short-circuit current and the ampere-turns caused by it may therefore be represented by the vector ATs. Since these short-circuit current ampere-turns have a certain effect upon the main field, the phase and size of the working current drawn by the motor from the source of power must be such as to combine with the short-circuit current ampere-turns to give the constant resultant magnetizing ampere-turns ATr, which, of course, must be in phase with the constant main field flux. A working current giving the ampere-turns ATa is therefore obtained which together with the magnetizing ampere-turns of the short-circuit current ATs gives the same field as in Fig. 3. The torque of the

motor is now equal to the product of flux, current, and the cosine of the angle of phase displacement β between the vector corresponding to the line current and the field, respectively. It will be seen, however, that the working current necessary to obtain this torque is considerably larger than under the assumed conditions of Fig. 3. Also, the watts input to the motor have been increased. If now resistance leads are introduced, thereby increasing the resistance of the short-circuited coil, the short-circuit current will of course be reduced and the relations shown in Fig. 5, intermediate between those of Figs. 3 and 4, are obtained. In this figure the short-circuit current and the corresponding ampere-turns ATs are smaller than in Fig. 4, and consequently the ampere-turns due to working current, ATa, and the working current necessary to obtain the same torque have been decreased. Also, the total watts input to the motor have been decreased.

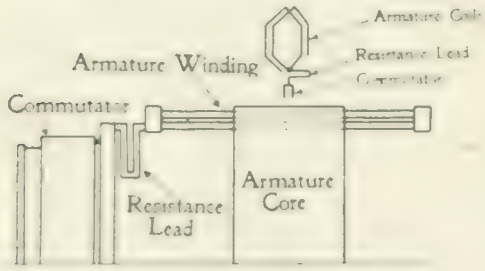


FIG. 6—SHOWING ARRANGEMENT OF RESISTANCE LEAD BETWEEN THE COMMUTATOR AND ARMATURE CORE

Schematic arrangement is indicated by the small diagram at top of figure.

Attention should also be called to the fact that an increased short-circuit current also increases the voltage which must be impressed upon the motor in order to obtain a certain torque. This is indicated in Figs. 4 and 5. By the change of the load currents, the vectors representing the ohmic drop in the motor change as shown in Figs. 3, 4 and 5. The absolute value of the gain made possible by resistance leads depends, of course, entirely upon the general design of the motor, the operating frequency, etc., but the example given is well within the conditions found in practice. Often the gain is considerably larger than shown, especially with motors for high frequency, such as 50 and 60 cycles, while on the other hand, it may be less than indicated in these figures in the case of motors for very low frequencies.

The principal disadvantage of the resistance leads is that they introduce a complication in the winding of the armature. With some constructions, this disadvantage has been very marked, while in other cases it has been reduced to practically nil. In this connection a description of a number of constructions which have been used will be of interest.

ARRANGEMENTS OF RESISTANCE LEADS

One possible arrangement of the resistance leads is shown in Fig. 6, where the leads are located between the armature winding and the commutator segments. With this arrangement, it is exceedingly difficult to place resistances of the proper value, in the available space. Moreover, it is difficult to support the leads in such a way as to make good mechanical construction. Therefore, this type is used very little at present. Most frequently, the leads are arranged in the slots of the armature, as shown in Fig. 7.

In order to obtain a lead which is free from self-induction, it is in many cases doubled up in the same slot; that is, the lead is connected to the armature winding at the commutator end, then enters the slot, is doubled on itself and returns in the same slot to the front or commuator end, where it is connected to the commutator bar. Two possible ways of doing this are shown in Figs. 8

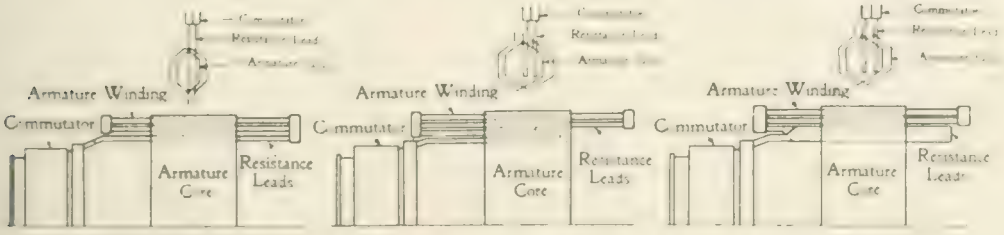


FIG. 7 FIG. 8 FIG. 9

SHOWING VARIOUS ARRANGEMENTS OF RESISTANCE LEAD WHEN PLACED IN ARMATURE SLOT BELOW THE MAIN ARMATURE WINDING

Schematic arrangements are indicated by the small diagrams above the figures.

and 9. The leads in these cases are arranged in the bottom of the slots. In some cases they have been arranged on top of the armature winding, with the idea of obtaining better cooling for the leads – a desirable feature, as there may be considerable local heating in the leads. The arrangement of the leads on top of the slot, however, has the disadvantage that the leakage fluxes across the tops of the slots induced by the armature current are rather large, as indicated in Fig. 10, and these leakage fluxes increase the self-induction of the armature coils, and as any increase of self-induction tends to increase the interrupted arc between brush and commutator bar, this is a disadvantage in its effect on commutation. It also leads to an increase of the armature reactance voltage, which of course is equivalent to a reduction in power-factor. In order to avoid this, and in order to obtain good cooling for resistance leads, it is customary with American engineers to arrange the leads at the bottom of the slot, and to provide the armature punching with

longitudinal ventilating holes underneath the slots, and force air through these holes. An armature punching intended for this arrangement is shown in Fig. 11. Resistance leads as shown in Figs. 8 and 9, serve merely as a resistance, since they are practically non-inductive and also since the effect of the currents flowing in these leads upon the field is eliminated, as explained above.

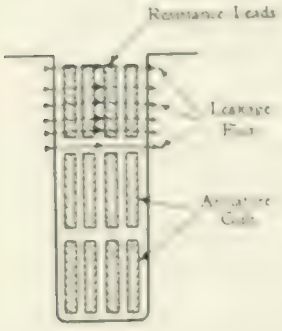


FIG. 10—SHOWING LOCATION OF RESISTANCE LEAD IN ARMATURE SLOT, WHEN PLACED OVER MAIN ARMATURE WINDING

Instead of doing this, it is possible to arrange the leads in such a manner that the currents therein will assist the other armature currents in giving useful torque. One possible arrangement of this type is shown in Fig. 12*a*.* The main armature windings in this figure are shown by full lines, while the armature coil which is just in a neutral zone, is indicated by a dotted loop *x*. The resistance leads are shown by dash-and-dot lines, and they are arranged to pass from the commutator end of the armature winding under one of the pole faces to the back of the armature, and back to the commutator end under the next pole face. The direction of flow of the working current in the main armature winding, as well as in the resistance leads, is indicated by arrows on the lines representing the windings, while the flow of the short-circuit current in the leads is indicated by arrows adjacent to the leads. It will be seen that while the short-circuit currents neutralize each other with respect to their effect on the flux of the pole faces, as they have opposite direction in two adjacent leads, the working current flows in both leads in the same direction as in the armature coils under the same pole faces. It is evident, therefore, that the working currents in the leads assist in giving motor torque. The arrangement of Fig. 12*a* is for a multiple winding; the same arrangement for a two-circuit winding is shown in Fig. 12*b*. The effect just described

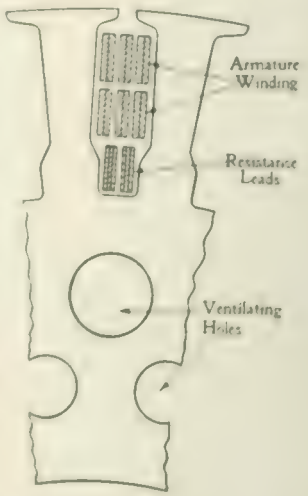


FIG. 11—SHOWING LOCATION OF RESISTANCE LEAD IN WINDING SLOT WHEN PLACED BENEATH MAIN ARMATURE WINDING

*For more complete treatment of this subject see article by Rudolf Richter, *Electrotechnische Zeitschrift*, 1906, p. 537.

can be increased if the resistance leads are made of coils of a number of conductors, instead of only two conductors. This is shown in Fig. 12*c*, where the resistance leads form complete coils of several turns each. In this case, the necessary resistance is obtained by having a large number of turns of good conducting material such as copper, instead of having just one turn of high resistance material. In other words, the preventive effect of the leads is the same, because the resistance is the same, while on the other hand, the useful effect of the working current in the leads is multiplied and increased proportionally to the number of turns. It is claimed that with this arrangement the output of small motors can be raised as

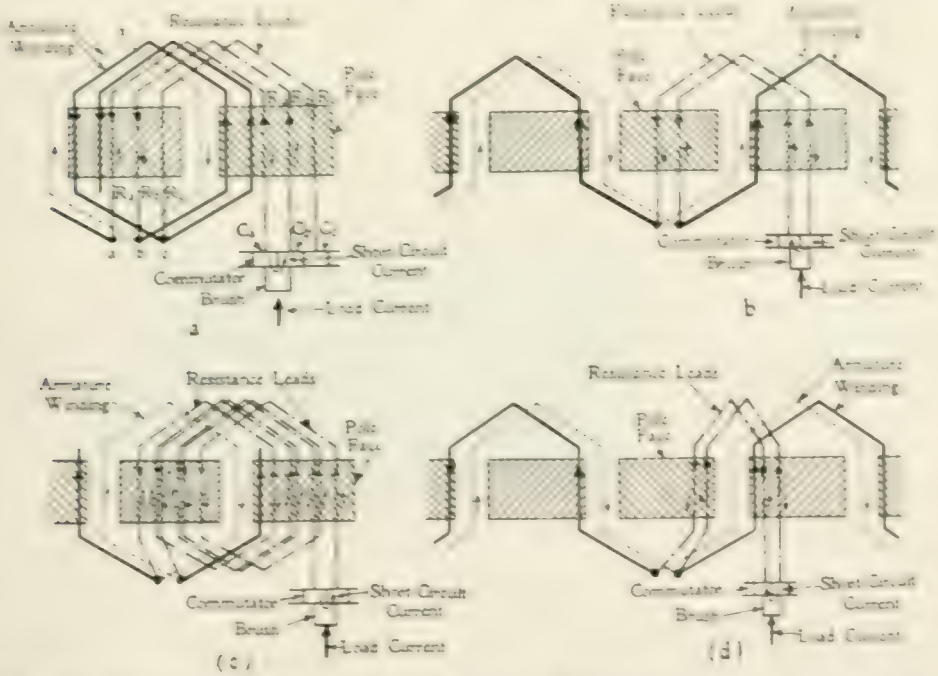


FIG. 12—SCHEMATIC DIAGRAM SHOWING CONNECTIONS AND ARRANGEMENTS OF RESISTANCE LEADS SO THAT CURRENT FLOW IN LEAD MAY PRODUCE USEFUL TORQUE

much as ten percent, and the efficiency as much as three percent. An armature constructed on this principle, with the resistance lead winding placed at the top of the slot above the main winding, as built by the Siemens-Schuckert Company, Germany, is shown in Fig 13. It is evident that with the arrangement of Figs. 12*a*, *b*, and *c* the resistance leads are no longer non-inductive. They will consequently have an increased reactance voltage; in other words, the arrangement is harmful to commutation. In order to reduce this to a minimum, the leads can be arranged as shown in Fig. 12*d*; that is, in such a manner that they will still be under the pole faces, and give a useful torque, while at the same time the end connections

and the leakage fluxes around them are reduced to a minimum; that is, the leads are arranged near the pole corners of the two poles, adjacent to each other. The harmful effect of the self-induction of the leads is not very serious if the number of turns is not too large. With only one turn, as shown in Figs. 12*a*, *b* and *d*, it can usually be neglected.

While the above arrangements increase the torque of the motor, it is evident that they introduce quite a number of additional members, such as conductors and connections, all of which naturally tend to reduce the reliability of the armature. This is the reason that these constructions are not used in America for railway work, the endeavor being to have the armature as simple as possible. This consideration has led to the arrangement which is shown diagrammatically in Fig. 14, the mechanical arrangement of which is shown in Fig. 7. In this case, the resistance leads pass only once through the armature slots, in such a manner that whatever current is flow-

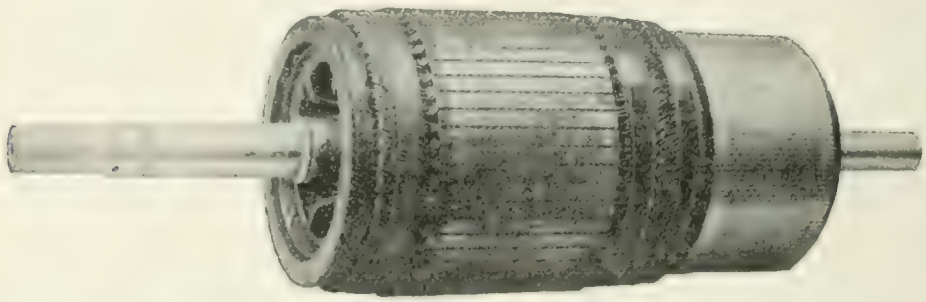


FIG. 13—SIEMENS-SCHUCKERT ARMATURE WITH WINDING AS SHOWN IN FIG. 12*c*

ing in such a lead assists the main winding, while on the other hand, the leads are made up of the fewest possible parts; that is, with a single conductor. At the same time this arrangement has the advantage that the additional self-induction introduced through the resistance leads is so small that it has no harmful effect on the commutation. Resistance leads of this type possess the highest possible degree of reliability if, by choosing the correct shapes and materials, they are properly constructed in such a manner as to take into account the centrifugal forces, vibrations and the like, as well as the effect of heat expansion and contraction, which are present in railway motors. Leads of this construction which have been in service for a number of years in a great many motors, are giving entire satisfaction. It might be mentioned in this connection that considerable trouble has been experienced in connection with motors employing some of the older constructions. Such troubles as were experienced in this country, were due, not so much to the burning

out of the leads, as generally assumed, but to difficulties caused by the fact that the leads did not stand the mechanical vibration and other strain, which in turn led to breakage and open-circuits. The absence of burn-outs of motors in this country is doubtless to be accounted for by the fact that from the first, the resistance leads have always been liberally designed. The breaking of leads at the commutator necks is not peculiar to single-phase motors as it obtains on direct-current motors in high speed service to a more or less degree, and nearly all single-phase motor car equipments have been used in this class of service.

In spite of the good results obtained with the latest type of resistance leads, it is nevertheless beyond question that they are a complication, and as such not wholly desirable. Any attempt to eliminate them is, therefore, fully justified, and an impartial discussion of the various schemes proposed, as well as their possibilities may, therefore, be of interest for subsequent consideration.

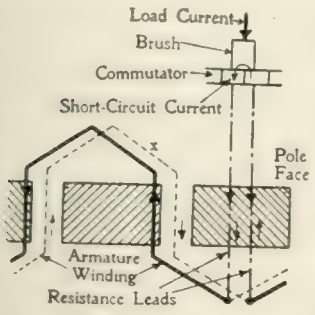


FIG. 14 — SIMPLER ARRANGEMENT TO PRODUCE THE SAME RESULT AS SHOWN IN FIG. 12. TYPE COMMONLY USED IN AMERICA

In how far and to what extent it will be possible and economical to eliminate the resistance leads is more or less a question for future experience. There is no doubt that even at present certain types of motors without resistance leads can be used to very good advantage in many industrial applications. Also for railway work, at very low frequencies, such as 15 to 18 cycles, good results have been obtained in Europe with motors without resistance leads. On the other hand, it may safely be predicted that for frequencies of 50 to 60 cycles the resistance lead will, in many cases, be a necessity for some time to come. The case of railway work with a frequency of 25 cycles, while being the most important, is, at the present time, the most disputed. While it seems fully possible that resistance leads may eventually disappear, in this case the actual experience in this line is very limited at the present time, since by far the greater number of 25 cycle railway motors in America and abroad, are still equipped with resistance leads.

THE MAINTENANCE OF ELECTRIC RAILWAY EQUIPMENTS.*

J. L. CROUSE

SUCCESSFUL maintenance of railway equipment involves the securing of the greatest reliability in service combined with the greatest economy. Ten years ago it was the practice, on many electric roads, to have one or more electricians whose duties were, to be on hand at all times and make hurried repairs to cars which broke down in service. In a word, in those days, the practice was to make repairs only when necessary and after the trouble occurred. Present day practice is to inspect all apparatus at regular stated intervals, and as far as possible to prevent trouble.

While the subject of reducing maintenance costs has been a very live and interesting topic during the past several years, nevertheless it may safely be stated that a considerable percentage of the small city and interurban roads today are wasting thousands of dollars annually through their apparent inability to depart from the old-fashioned method of waiting until trouble occurs before giving attention to the equipment.

The principal duties of the writer during the past six or eight years have been to investigate causes of delays in service, and maintenance costs; to make recommendations for the correction of the former, and ways and means for the reduction of the latter. During this time every effort has been made by manufacturers toward improving and developing railway apparatus and this is certainly the surest means of promoting the industry since lower maintenance costs insure better financial returns. During this period many railway repair shops have been visited and, to be candid, the writer has frequently wondered how some companies get along as well as they do with the equipments in the conditions they were found. On the other hand, there are a great number of roads where the equipments are well maintained, and the cost sheets at the end of the month as a rule bear out this fact.

There is seldom an opportunity to compare consistently the maintenance costs on one road with those on another. This is due to the fact that a great number of factors determine the cost of upkeep. Among these are; line voltage, weights of cars, schedule

*From a paper read before the Central Electric Railway Association, April 4th, 1912.

speeds, stops per mile, gear ratios, capacity of the equipments, air brakes, condition of the track, type of motors or control, training of the motormen, wear allowed on axle bearings before removal, wear allowed on armature bearings before removal, wear allowed on gears before removal, the opportunity for and facilities provided for inspection and repairs.

Some railroads house, inspect and make all repairs at one place and have sufficient numbers of spare cars so that regular periodic inspections may be made, while others with similar mileage and similar equipment are obliged to lay up cars at various points and operate considerable dead mileage in order to make periodic inspections or repairs, resulting in spasmodic attempts instead of continued, studied efforts to keep every detail in good condition.

MAKE-SHIFT REPAIRS

The average make-shift repair job, while made for economical reasons as a rule, proves to be very expensive in the end. For example, in many instances an old armature is repaired by putting in one or two new coils, or splicing out a damaged coil, the idea being that it is cheaper to do this than to re-wind the armature. In most of these cases the entire new set of coils would cost approximately $35, but when completely rewound the armature would be good for at least a couple of years' steady service, while the make-shift repairs usually result in another breakdown in a month or so. The cost of bringing in the car and opening up the motors, plus the loss of traffic and time the equipment is out of service, etc., will usually result in an expense which is nearly double the cost of a new set of coils.

Numerous instances have also been seen where cars were brought in and repairs made on one motor, and the remaining motors and equipment on the car were not even examined because they had not been reported as defective. Now the larger portion of the expense is caused by bringing the car in for repairs and, while it is in the shop, all the equipment should be put in good shape before the car is sent out again.

Where this make-shift kind of work is the practice, the records usually show items about as follows:

July 1st—Car No. 242 in shop; No. 1 motor, grounded armature.
July 3rd—Car No. 242 in shop; brake trouble.
July 4th—Car No. 242 in shop; No. 2 motor, grounded brush holder.
July 7th—Car No. 242 in shop; controller trouble.

Such records tell their own story and indicate lack of thoroughness of inspection when the car was first brought in the shop for repairs.

The proper way to correct this is for the manager or superintendent to insist on reports that will show the fact that, although the car was in the shop a few days previously, this recent defect was not discovered, and to take sufficient interest on each occasion to ask about it; this for the purpose of conveying to the minds of the shop men that he is watching these details. In this way he will make them more thorough in their work.

In all cases where cars are taken out of service to be repaired, a special report should be made to the manager, showing the cause of trouble and date, and the name of the inspector who made the previous regular inspection; the foreman should be required to state in this report whether the trouble could have been prevented if the car had been properly inspected, or whether it was unavoidable. Suitable report forms may be provided for this purpose.

CONDITIONS OF SHOPS

In visiting various shops the condition of the equipment could frequently be foretold by an inspection of the shop, storeroom and scrap pile. Often motor and control parts were found strewn over the floor; little or no material was found in the storeroom, as supplies were used up as fast as received, or cars were laid up waiting for them. Large scrap piles contained cast iron and steel mixed together; also, brass and copper were found in the same bins, or frequently piled out in the yard. Parts were found that might have been repaired by the men at odd times, by removing the worn parts, such as brush holders, springs and hammers, control fingers, etc. A considerable saving can be made by sorting such materials properly, and not allowing them to accumulate for too great a length of time.

Where the above conditions were noticed, it followed that no system of record was kept. On the other hand, with a clean shop, usually would be found a well-kept storeroom, a small scrap pile, and the equipments in an up-to-date condition, with the master mechanic or foreman prepared to give practically any data asked for, from a well-kept record.

INSPECTION AND GENERAL OVERHAUL

The frequency of inspection periods as well as of general overhauling must be determined by service conditions and the equipment

itself. Some roads have established inspection on the mileage system while others inspect on a five or ten day basis. The general overhauling period must be determined by the life of bearings, pinions, commutators, trucks and brake rigging, but in no instance should it go longer than one year.

Inspection—It seems to be the general practice on a great majority of roads to inspect on a 1 000 mile basis. At this period each car should be placed in the shop and all detail parts thoroughly examined, such as contact tips, shunts, cotter keys, arc shields, carbon brushes, brush tension, etc. The control and motors should be blown out with compressed air. All wearing parts and insulators should be wiped clean. Lubrication of bearings should be cared for by seeing that they are properly packed, with the waste firmly pressing against the journals, and by gauging the oil in bearings to see that they show the proper quantity. In fact, every detail on the car should be put in shape to run until the next inspection.

General Overhauling—The intervals between overhaulings should be determined by service conditions. When overhauling an equipment, all of the apparatus on the car should be taken apart. The control and auxiliary apparatus should have the insulating parts thoroughly cleaned and, if of fibrous material, should be thoroughly painted with a good insulating varnish or shellac, the latter preferred, as it gives a durable, hard finish, which can easily be cleaned. All badly worn parts should be replaced. If not entirely worn out, they can be used on other cars to replace broken parts or parts worn too badly to last until the general overhauling.

Motors—The motors should be taken apart, and field coils and brush holders removed from the frame. Field coils and wiring should be thoroughly cleaned and painted with a good grade of moisture-repelling insulating compound. The armature should be blown out with compressed air, the commutator turned and undercut, and any loose bands replaced. It is good practice to spray the armature thoroughly with a good finishing varnish. By the use of a spray the varnish will penetrate all of the crevices and materially strengthen the insulation. The brush holders should be carefully inspected, and badly worn parts replaced. It is also very important to check up the size of carbon brushholders and keep a careful record of these sizes, in order that brushes can be ordered with a minimum clearance in the holder, which should not be more than five to ten thousandths of an inch.

Car Wiring and Lights—The car wiring should be inspected carefully to see that there is no chafing and that all connections are tight and properly cleated, and all exposed insulated wire should be painted.

Brakes and Mechanical Parts.—The brake rigging apparatus and mechanical parts should be very carefully inspected and any doubtful parts should be renewed. These parts are of vital importance, as a defect in either may cause a derailment or accident.

Air Compressor.—The motor on the compressor should be treated in the same manner as the car motors. The compressor bearings should be carefully gauged, and if excessive wear is found, the bearings should be renewed. The condition of the gears should be carefully checked up. It is advisable to note whether the wear on packing rings and valves is excessive. After the compressor has been thoroughly cleaned and re-assembled, it should be tested to see that there are no leaks in the gaskets or valves.

Reversing Cars.—One of the most serious abuses on the part of motormen which has been brought to our attention of late is the practice of reversing on four-motor equipments. On some roads the motormen apparently are permitted to do this on the slightest provocation. This practice is the direct cause of a great many car failures, such as broken gears and pinions, short-circuited commutators, burned brush holders, burned reversers, etc. Whenever a motorman finds it necessary to throw the reverser in order to avoid an accident, the matter should be reported so that an inspection may be made of the commutator, brush holders and reversers and so that, if necessary, they may be cleaned up; in this way the probable delay which would occur in service if the damage were permitted to continue after the car has been "bucked," will be avoided.

GRADE OF LABOR

The maintenance and inspection problem is comparatively easy to solve on the large urban properties, where special men, such as controller inspectors, air brake inspectors, motor repair men, etc., may be trained for the different grades of work. On the majority of smaller properties there is not enough work of one character to warrant such an organization; therefore, a few all-round handy men must be employed, and in such cases it is usually economy to secure high grade men.

A great many roads make the serious mistake of employing the cheapest labor for oilers because it is rather a dirty job, while it is a fact that the most expensive repairs are caused by improper lubrication. The Galena Signal Oil Company is doing a good work along the line of improving lubrication conditions by sending out men to deliver lectures in various shops on the subject of lubrication.

TECHNICAL GRADUATES IN RAILWAY SHOPS

The large railway companies have regular apprenticeship courses for young men in their shops, and special courses for tech-

nical graduates. The writer would strongly recommend that the managers of small properties arrange their organization so that a fairly attractive position will exist for the technical graduate, such as assistant foreman, or assistant to the master mechanic or superintendent. The smaller roads offer much better opportunities to the technical graduate who is anxious to secure experience than do the larger properties on account of the fact that each day he is brought in close contact with every detail in connection with the maintenance and repair of the entire equipment. On the larger properties he must work in some one department or section of the shop at some particular work, and to a certain extent does not get the benefit of exercising his judgment and resourcefulness in seeing the car as a whole brought in for repairs and the making of all such repairs as are found necessary and consistent with the requirements of the transportation department.

In general, the work in a small shop may not appeal to the average technical graduate; this is probably due to the fact that he thinks the opportunities for advancement are greater in the larger corporations and also because there is a feeling among the rank and file of the workmen that the so-called book learning does not amount to much. Hence, life is not very pleasant for the technical graduate among them, unless he happens to have sufficient good sense to drop all his college mannerisms and become one of them, and make it clear to all of his fellow workmen that he does not consider himself any better than they are, and that he is there to learn from them and in turn to give them the benefit of his technical knowledge if they desire such information.

A great many small properties could well afford to create a position, such as engineer of car equipment, and have this man report to the master mechanic and make it his duty to look after all records and see that proper record is placed on file showing sizes and dimensions of all axles, gears and pinions, armature and axle bearings, truck and wheels, etc., and work toward standardizing all details, such as air piping, hangers, etc., and in this way reduce unnecessary stock; also to keep records showing life of all wearing parts, such as wheels, gears, trolleys, bearings, etc. He should also supervise all methods of testing armature fields, circuit breakers, etc., and check up old gear ratios and determine whether power is being wasted, etc.

On the average small road, the manager or superintendent looks to the general foreman or master mechanic for everything. In the majority of cases he is a very good man and gets along fairly well, but he has no time to look into economics and check things up, and as a rule has no one under him with a sufficient knowledge of technical details to whom he can delegate these duties; and accordingly they are neglected. It is for such situations that we recommend the selection of a technical graduate.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 209 Ninth Street, Pittsburgh, Pa.

724—Operation of 220 Volt Direct-Current Motor on 500 Volts—It is desired to operate a 13 horsepower, 52 amperes, 220 volt, 875 r.p.m. shunt wound direct-current motor on a 500 volt circuit during a portion of the twenty-four hours. Would it be practicable to do so by means of resistance connected in series or by other simple change in connections? If so, please give diagram. M.C.O'D.

If the load is practically constant it will be necessary only to connect resistance in series with

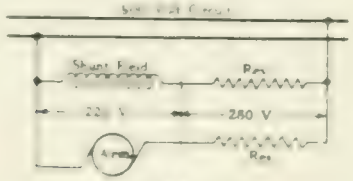


Fig. 724 (a)

the field and armature as shown in Fig. 724 (a). The amount of resistance in the armature should be equal to $\frac{280}{\text{armature current}}$ ohms. The amount of resistance in the field should be $\frac{280}{\text{field current}}$ ohms. If the load is variable within narrow limits this will still give fairly satisfactory results, though the speed will vary considerably due to variation in voltage drop across the permanent resistance. If the load varies over wide limits satisfactory operation cannot be secured. J.M.H.

725—Electric Cutting of Iron and Steel—I should like to obtain information and references on the subject of a complete equipment for use in electric cutting of iron and steel. In the particular case in question it is desired to cut billetts 6 in. by 6 in., and 24 in. "I" beams. G.R.S.

As mentioned in an article on electric welding in the JOURNAL for January 1908, p. 25, such an outfit can be used for cutting odd pieces and where a ragged edge and the loss of a certain percentage of material is of little account. However, for commercial work on a larger scale the oxy-acetylene or ox-hydric process is to be preferred. See description under "Cutting of Metals" in article on "Autogenous Welding" in the JOURNAL for August 1909, p. 470. Equipments for the former process are sold both by the Linde Air Products Company, Buffalo, N. Y. and the Davis-Bournonville Company, Marion, N. J., and the latter by the American Ox-Hydric Company, Milwaukee, Wis. C.B.A.

726—Unsatisfactory Division of Load Between Two Direct-Current Generators—Two direct-current generators of 35 kw., 300 amperes, 115 volts rating are direct connected to a 100 hp engine which operates at approximately 313 r.p.m. When operating under a load of 50 amperes one of the machines gives only 70 volts, and when the load is increased to 200 amperes the voltage on this machine drops to zero. Upon paralleling the two generators, this machine does not carry any of the load. The armature core is not symmetrically under the fields, but is offset about an inch at the rear end. Would this account for the trouble? R.T.G.

The trouble could not be accounted for by the position of the armature relative to the field; however, there might be some end

thrust on the bearings, as the tendency of the field poles when excited is to pull the armature into a central position in the field. There would not be a drop of voltage due to this cause. This is probably due to the series field coils being reversed, so that instead of increasing the excitation as the load increases, the excitation is decreased. In other words, the connections of the series field coils are reversed so that the series field is in opposition to the shunt field. This can be checked by first running the machine with shunt field only, and noting the polarity of the brushes; second by running the machine with the series field connected and the shunt field open and again noting the polarity at the brushes. If the polarity is different in the two cases, the connections should be changed so that the current will flow in an opposite direction in the series field. In short, the series and shunt windings should go so connected that they will produce the same polarity. W.A.D.

727 — Books on Switchboards — Please give references to good books covering the explanation, with connection diagrams, of switchboards. F.L.C.

So far as we are able to judge, practically the only book which gives diagrams within five years of being up-to-date is "Electric Power Plant Engineering" by J. Weingreen, which was reviewed in the JOURNAL for March 1910, (Price $5.00 net). We would call your attention to the series of articles on "Meter and Relay Connections" by Mr. H. W. Brown appearing in issues of the JOURNAL from May 1909 to June 1910, which will serve to cover a large number of important cases. Furthermore, actual diagrams and descriptions of various switchboards were covered in a series of articles by Mr. H. W. Peck in the JOURNAL for December 1904 and January, March, May, June, October and December 1905. The Eight Year Topical INDEX gives reference to these and other articles on the subject of switchboards which would doubtless be of assistance to you. C.H.S.

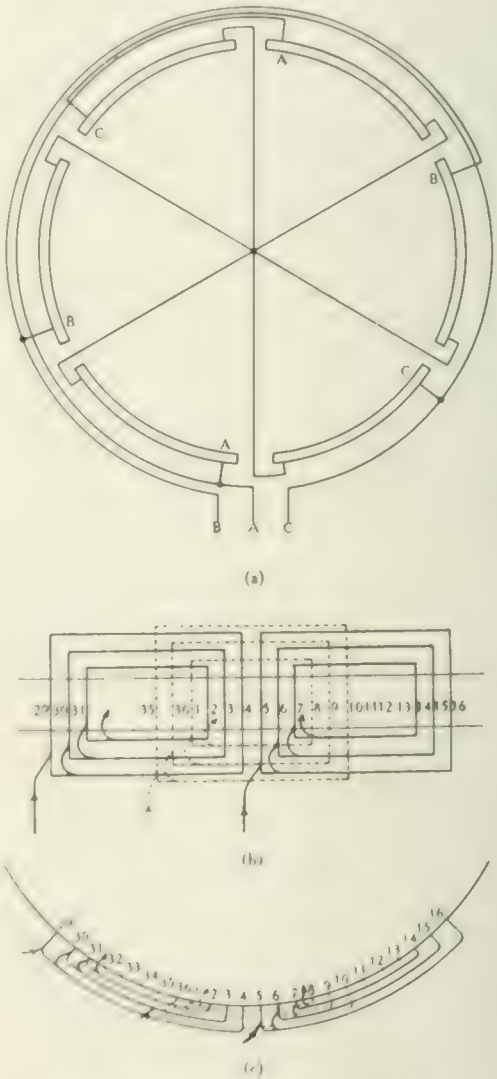
728—Effect of Operating Voltage on Heating of Alternator— We have in operation a 2 000 k.v.a. three-phase 60 cycle 2 000 volt revolving field generator which used to be operated at about 2 200 volts. The machine ran so hot at full load that the question was taken up with the manufacturers and they sent out a man who after investigating had the voltage cut down to about 2 050 volts. The machine continued to run hot at full load but not as much so as before. For the same k.v.a. on the machine the armature current at the low voltage is higher than at the high voltage but of course the exciting current is a little less. I would like you to explain how this condition is brought about. F.T.P.

The decreased heating with lower operating voltage is due to the decreased core loss. In a large generator the core loss is several time the armature copper loss, so that while the reduction in operating voltage does mean an increased copper loss for the same k.v.a. load, the increased copper loss is usually much less than the decreased core loss. For this reason the temperature of the core will be less with the lower voltage. F.D.N.

729—Transpositions for High-Tension Circuit— *a*—On a 66 000 volt transmission line fifty miles long, made up of one three-phase circuit, is transposition advisable; if so how many transpositions are required? *b*—Can telephone companies having lines nearby obtain damages for telephone line trouble due to the high-tension line? *c*—Can you give an explanation of the effect of transposition on a three-phase high-tension line circuit, or give a mechanical analogy of three-phase circuit transposition? *d*—Is there any effect, good or bad, resulting to the high-tension circuit itself with or without transposition? J.A.F.

a—The transposition of the conductors on any transmission line is carried out for the purpose of equalizing the electro-magnetic induction of the conductors of that transmission line on neighboring circuits. In order to obtain freedom from electro-magnetic induction it is necessary that the average distance from any neighboring circuit to each of the three conductors of the transmission line be the same, and this can of course be accomplished by transposing the conductors of the transmission line. The number of transpositions should be such as to make the sections of the transmission line a multiple of three. That is either three, or six, or nine sections, etc. *b*—This question is one for lawyers to answer, not engineers. *c*—As indicated in the answer to *a* electro-magnetic induction of a transmission line on neighboring circuits is eliminated when the average distance or exposure from each transmission line conductor to the neighboring circuit is made the same. The outgoing current on a transmission line is always equal to the return current, the outgoing being on one conductor and the return on the other two. It is evident, therefore, that if the exposure of all conductors of the transmission line on the neighboring circuit be made equal there will result no electro-magnetic induction. This, however, does not necessarily apply to electro-static induction. *d*—So far as the effect upon a transmission line itself is concerned, no good or no harm is done by transposing. It is only to alter the effect of a transmission line upon neighboring lines that transpositions are carried out, not for any effect within the transmission line itself. P.M.L.

730—Grouping of Coils in Multi-Speed Induction Motor—The diagram of connections of Fig. 730 (a) shows an arrangement which recently came to the writer's attention, as used on a motor of German manufacture, rated at five hp, three-phase, 60 cycles, 220 volts, 1740 r.p.m. full load speed. There are only six groups of coils, using a parallel connection. Each group consists of three coils connected in series. There are 28 turns per coil of No. 13 wire. All motors that I have investigated heretofore have one group of coils per pole, per phase, whether a series or parallel connection is used. With the winding arrangement shown on the sketch, at first glance it would seem that the motor was wound for two poles, but on tracing out the connections and instantaneous values of current it will be found that a four-pole connection can be obtained, but it appears to the writer that this ar-



Figs. 730 (a), (b), and (c)

rangement would be likely to cause unbalancing. J.H.K.

The five hp, three-phase 60 cycle, 220 volt, four-pole motor of German manufacture has an ordinary arrangement of groups for consequent poles. Instead of distributing the coils over all of the poles, they may be distributed as well over the consequent poles only. All of these different schemes of grouping and connecting have been described in the series on "Winding of Dynamo-Electric Machines," in the JOURNAL for May and June, 1911, in articles by Messrs. Bartmess and Specht. Note particularly Figs. 141, p. 475, and 148, p. 572. H.C.S.

731—Transformer Connected as Booster—Please indicate how a transformer may be connected as a booster. J.D.L.

The connections for a booster transformer are simply to connect the primary in shunt across the circuit whose voltage is to be boosted and the secondary in series with one side of the line. The primary then acts as an exciting winding and the secondary is the boosting winding. The transformer is thus made to serve practically as an auto-transformer. With the secondary connected in one way relative to the primary, the transformer will raise the voltage; when connected in the opposite way (i.e. with either the primary terminals or secondary terminals reversed) the transformer will have the effect of lowering the voltage by a similar amount. The simplest way of determining which way the given unit should be connected to raise the voltage is by trial. See article on "Alternating-Current Potential Regulators" in the JOURNAL for August 1908 page 448; also No. 320, November 1909. For information regarding connections and method of operation of induction type regulators see article in the JOURNAL for November 1911, page 1008. E.E.L.

732—Corona Discharge—What is meant by corona discharge? J.D.N.

When the intensity or potential gradient electrical stress in air at any point between two charged bodies becomes greater than a certain critical value, a molecular change takes place in the air by which it becomes conducting. The conductance of electricity is accompanied by luminosity, and since the stress is always highest at the surface of one of the conductors, the conducting air forms a luminous "corona" or crown on the surface. When at the surface of a conductor this conductance of electricity takes place, accompanied by luminosity, it is commonly referred to as a "corona discharge." C.F.

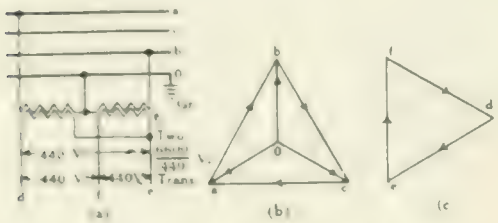
733—Operation of Horn Gap Lightning Arrester—How does the horn gap lightning arrester break the flames of current after the lightning has discharged. J.D.N.

The horn gap used in series with some current limiting devices, such as a resistance, tends to suppress an arc by the upward current of air caused by the heat of the arc itself. This sweeps the arc upward and stretches it until the resulting drop across the arc and reduction of current value cause the arc to break. This characteristic becomes obliterated by the tenacity of the arc at 40 to 60 amperes. On the other hand, very small currents do not make enough heat to rise properly and often hang tenaciously at the low corners of the horns. This may occur with currents up to 0.5 ampere. R.P.J.

734—Vector Relation with Transformer Connection—Please explain the vector relation of primary and secondary voltage of the transformer connection shown in Fig. 734 (a). J.T.C.

Denote the grounded (or neutral) line by *O*, the lines to which the primaries of the transformer are connected by *a* and *b*, and the fourth line by the letter *c*. Then the voltages from neutral to the respective lines and the voltages between lines are given by Fig. 734

(a), (b) and (c) representing the e.m.f's between line *O* and wires *a*, *b* and *c* in magnitude and phase. Denoting the low-tension terminals by *d*, *e* and *f* Fig. 734 (c), it follows that:—The e.m.f. between *d* and *e* is in the same phase as the e.m.f. between *O* and *a* represented by line *de* Fig. 734 (c); e.m.f. from *e* to *f* is in the



Figs. 734 (a), (b), and (c)

same phase as the e.m.f. between *O* and *b*, represented by line *ef*; the e.m.f. between *f* and *d* is in the same phase as the e.m.f. between *O* and *e*, represented by line *fd*.

C.F.

735—Design Details of Commutator Watthour Meter—What is the purpose of the holes in the aluminum disk of some makes of commutator type watthour meters?

We do not know that they are of any use. They are probably put in because the same disk is standard for other meters. In an alternating-current wattmeter, for example, such holes would serve to prevent creeping. W.B.

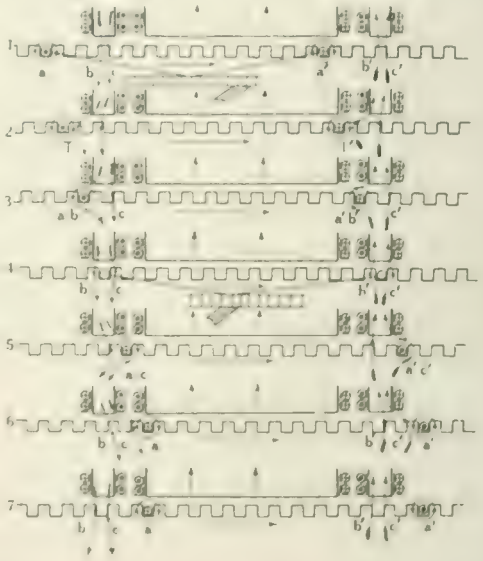
736—Tests for Comparing Carbon Brushes — Please indicate the most important tests for comparing carbon brushes for direct-current commutators. Two or three different grades and makes of brushes would be compared. J.E.I.

It has been found, as a rule, that laboratory tests are of little or no value in determining whether a brush is suitable for a direct-current machine. The only way we have been able to get satisfactory results is to try the brushes on the machine or type of machine in question, and determine from actual service conditions what brush or brand of brushes will give the best results. Such things as the hardness, the texture, the conductivity, finish, etc., can be judged by an examination of a few brushes, but these do not give a measure of the service which may be expected of the brush when used on a particular machine. It has also been found that the different direct-current machines require different grades of brushes, and this can only be determined, as a rule, by actual service tests. C.E.S.

CORRECTIONS

In the article on "Relation of Flywheel and Motor Capacity" in the March, 1912 issue, the first line in the subtitle to Fig. 2, p. 274, should read, "Since the speed drop and torque are assumed proportional."

In the diagram Fig. 5, of the article on "Commutation and The Interpole Railway Motor" in the JOURNAL for October, 1910, p. 764, the usual convention regarding the method of indicating the relation between direction of flux and direction of current in a conductor



was not followed. Moreover, in the seven diagrams, the direction of flow of current in the right hand interpole windings should have been indicated as opposite to, instead of the same as, the direction of flow in the left hand interpole windings. The revised set of diagrams herewith will serve to cover the matter correctly.

PERSONAL

Mr. C. F. L. Brown, the well known electrical engineer of Baden, Switzerland, recently arrived in San Francisco on a trip around the world. On his trip across the United States he will stop at a number of cities and in New York will be tendered a reception at which he will be formally notified of his election to honorary membership in the American Institute of Electrical Engineers.

Mr. C. C. Owens has recently been placed in charge of the Detroit district sales office of the Westinghouse Electric & Mfg. Company, with the title of District Manager. Mr. Owens was born in 1877 near Annapolis, Md., and graduated from Columbian University, Washington, D. C. He entered the employ of the Westinghouse Company in 1899, taking the apprenticeship course for three years, after which he spent four years in the engineering department, specializing on switchboards and controllers. For the last eight years he has been connected with the New York sales office, having had charge of the industrial and power division for the two years previous to his transfer to Detroit.

Mr. Frank D. Chase, architect of the Western Electric Company, has opened offices in the People's Gas Building, Chicago, for the practice of architectural and industrial engineering, making a specialty of manufacturing plants and mercantile buildings.

The appointment of the following works directors has been announced by the management of the Westinghouse Electric & Mfg. Company, effective March 1: Mr. J. McA. Duncan, formerly assistant manager of works, to be director of works accounting; Mr. E. R. Norris, formerly assistant manager of works, to be director of manufacturing operations; Mr. A. B. Reynders, formerly assistant to manager of engineering, to be director of production; Mr. Wm. Cooper, formerly engineering inspector, to be director of buildings and equipment; Mr. C. B. Auel, formerly assistant manager of works, to be director of standards, processes and materials; Mr. C. W. Johnson, formerly assistant manager of works, to be general superintendent.

Mr. W. T. Bothwell, formerly in charge of the detail testing department, has been appointed engineering inspector.

Mr. B. R. Shover, electrical engineer for the Carnegie Steel Company in the Youngstown district, has been appointed superintendent of the new Briar Hill Steel Company, Youngstown, Ohio.

Mr. Aldis E. Hibner, power engineer of the Livingston-Niagara Power Company, has recently resigned and accepted the position of electrical commercial engineer of the Empire Gas & Electric Company of Auburn, New York.

Mr. N. B. Davis, of the general engineering department of the Westinghouse Electric & Mfg. Company, has recently been transferred to the Chattanooga sales office.

WESTINGHOUSE CLUB BANQUET

The annual banquet of the Westinghouse Club was held at the Fort Pitt Hotel, Pittsburgh, Pa., on March 16, about 500 being present. Mr. E. M. Herr, president of the Westinghouse Electric & Mfg. Company, acted as toastmaster. The other speakers were: Col. H. G. Prout, vice-president and general manager of the Union Switch & Signal Company; Mr. A. L. Humphrey, general manager of the Westinghouse Air Brake Company; Mr. T. C. Clifford, of the Pittsburgh Meter Company; Hon. Geo. W. Guthrie, ex-mayor of Pittsburgh; Mr. G. E. Tripp, chairman of board of directors of the Westinghouse Electric & Mfg. Company; Mr. J. J. Jackson, attorney for the Westinghouse Electric & Mfg. Company, and Mr. E. H. Sniffin, sales manager of The Westinghouse Machine Company.

OBITUARY

Rear Admiral George W. Melville, U. S. N., retired, died at his home in Philadelphia on March 17, at the age of 71.

Mr. Daniel D. Dickey, general manager of the National Carbon Company, died in Cleveland on March 8. Mr. Dickey was born in Pittsburgh in 1853 and graduated from what is now the University of Pittsburgh.

Mr. Henry W. Spangler, professor of dynamical engineering of the University of Pennsylvania, died in Philadelphia on Sunday, March 17th.

PERSONAL

The following engineering apprentices have recently left the apprentice course of the Westinghouse Electric & Mfg. Company to take permanent positions with the firms indicated after their respective names: Mr. G. E. Newell, Dallas district office, the Electric Company; Mr. D. H. Cronheim and Mr. S. O. Kelly, Birmingham Light & Power Company, Birmingham, Ala.; Mr. W. F. Doherty, engineering department, Westinghouse Lamp Works, Bloomfield, N. J.; Mr. O. F. Knight, Buffalo district office, the Electric Company; Mr. W. C. Rathell, Cincinnati district office, the Electric Company; Mr. G. I. Thatcher, Second Lieut., Coast Artillery, Fort Monroe, Va.; Mr. Geo. S. McElroy, Buffalo district office, the Electric Company; Mr. S. M. Anson, Boston district office, the Electric Company; Mr. R. C. Allen, Boston district office, the Electric Company; Mr. H. K. Hayden, salesman, Walter E. Hill & Company, jobbers, Baltimore, Md.; Mr. J. S. Espy, Pittsburgh district office, the Electric Company; Mr. H. C. Holtzclaw, New York district office, the Electric Company; Mr. C. S. Andrew, Indianapolis office, the Electric Company; Mr. A. J. Walrath, Detroit district office, the Electric Company; Mr. J. B. Crosswege, Westinghouse Air Brake Company, Wilmerding, Pa.; Mr. A. G. Strang, Coast Artillery Corps, U. S. Government; Mr. Don Castle, Jamestown Electric Company, Jamestown, N. Y.; Mr. Frank W. Horning, W. H. Shott, electrical contractor, Chicago, Ill.; Mr. H. E. Buchanan, Long Island Railroad Company, New York City; Mr. W. E. Baker, in charge of efficiency department, Selby Shoe Company, Portsmouth, Ohio; Mr. L. L. Dewy, Brazil Railway Company, Sao Paulo, Brazil; Mr. Drewry Kasselsam, Rochester Railway & Light Company, Rochester, N. Y.; Mr. B. M. Hallbert, Hydro-Electric Commission of Ontario, Canada; Mr. Paul N. Pittinger, Engineering department, Pittsburgh Gage & Supply Company, Pittsburgh, Pa.

The following men have taken permanent position with the Westinghouse Electric & Mfg. Company at their East Pittsburgh works: Mr. H. E. Applegarth, D. & S. sales department; Mr. G. W. Lynn, D. & S. sales department; Mr. S. H. Warden, R. & L. sales department; Mr. G. E. Morrison, I. & P. sales department; Mr. H. B. Reynolds, power house; Mr. Paul Simpson, service department.

A. I. E. E. CONVENTION

The Industrial and Power Section of the American Institute of Electrical Engineers will hold a convention in Pittsburgh on April 25-26-27.

The annual convention of the Institute will be held in Boston at the new Copley Plaza Hotel, June 25-28.

NEW BOOKS

"Telephony"—Samuel G. McMeen and Kempster B. Miller. 948 pages, 671 illustrations, 7 by 10 inches. Published by the American School of Correspondence, Chicago, Ill. Price, $4.00.

This comprises a comprehensive and detailed exposition of the theory and practice of telephony. The book is divided into 53 chapters, is profusely illustrated, and printed in clear, easy-reading type. The book is apparently quite up-to-date. The theory and application of Pupin or loading coils is described, also various forms of relays, automatic and automanual systems, etc. After taking up in detail the various kinds of subscriber's apparatus, a number of chapters are devoted to the different forms of switchboard apparatus, line and underground construction, service connections, testing, etc. To one who wishes to gain a general knowledge of telephony in all its branches, this book should prove of much value. It is written in the so-called correspondence school style and is one of the most elaborate works extant on this subject.

"Power House Design"—John F. C. Snell. 448 pages, 181 illustrations, 17 plates. Published by Longmans Green & Company, New York City. Price, $6.00.

The treatment of power house engineering in its broader aspect requires a large fund of knowledge in order to put forward proficiently the variety of problems which present themselves in this work, involving the choice of location, equipment and structure concordant with all the conditions, mechanical and electrical, and the establishment of the most economical station viewed from the standpoint of the source of every supply and the facility of its delivery, and as well as the operating factors customarily entailed. In face of the wide reputation the author enjoys in the engineering profession both at home and abroad (Great Britain), and the vast experience actually acquired in the direction of such undertakings, it is almost unnecessary to state his qualification for successfully coping with the

subject. Moreover, the author has not rested content with his own personal observations, but has, in a limited way, drawn upon other authentic information. The author thus has throughout taken much pains to insure the quality of his book. At the outset, the very root of the subject is discussed in the classification of the different characters of demand which call for a power supply station, and an outline of the electrical conditions generally prevailing is given. Chapter II presents a careful digest of the factors which govern the choice of sites for a new plant, denoting proper regard for future extension and growth of the community or industry. Building considerations appear in Chapter III, embracing architectural features, foundation requirements, construction materials, chimneys, provisions conducive to efficiency in operation of the plant and relative cost data. The following four chapters (IV, V, VI and VII) are devoted to steam power plant details and are taken up in a corresponding analytical manner, and in addition to essential topics of boilers and boiler-room design, stokers, draft piping, coal and ash handling machinery, economizers and water treatment are given attention. Similarly, the chapters on condensers, artificial cooling systems are dwelt upon. There follows specific chapters on gas power and water power plants. They likewise deal with the various types of machinery and auxiliaries usually employed, and the conditions favorable to their use. The concluding three chapters (IX, X and XI) apply to switchboards and switchboard apparatus, and general electrical equipment and substation design. The book is supplemented by brief appendices on water tube boilers, velocities in circulating water pipes, electricity regulations (Great Britain), cooling towers, and tests of steam feed pumps. A large number of plates and illustrations are contained, quite a few representing American installations. General data relative to the installation costs of different machinery has been supplied. There is an apparent leaning of the author towards some designs of power house equipment, boilers, stokers, turbines, etc., evidently the result of his own personal experience. Those who may be more familiar with other types and condition may, in some cases, hold slightly different opinions. This certainly is in no sense an objection, but is only characteristic of the individuality and definiteness interwoven in this work. It is plainly a book of great value to the power plant owner and engineer.

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NEW BOOKS.

"Steam Power Plants, Their Design and Construction"—Henry C. Meyer. 419 pages, 97 illustrations, 15 plate proofs. Published by McGraw Hill Book Co., New York City. Price, $2.00.

This is the third edition of the author's work originally published in 1902. It is intended to be of value to those in charge of mill, factory or electric generating stations who have occasion to design and purchase steam power plants and apparatus. While much valuable permanent information is contained, unfortunately for this work, there have been such marked changes in power plant design in the last ten years that slight modifications and revisions can hardly bring such a work up to date. The author has attempted to make the book apply to current practice by adding a chapter on steam turbines and also some other new material. It is undoubtedly a fact, however, that such plants as the original Waterside station in New York are the last of their kind which will be installed and that in any future installations the steam turbine will replace the large steam engine. The fact that turbines take steam at a fairly uniform velocity rather than at intervals, as is the case in steam engine practice, has resulted in some important modifications in steam piping practice also. The general discussion, however, will be found of interest and value to central station men.

"High-Efficiency Electrical Illuminants and Illumination"—Rodin W. Hutchinson, Jr. 278 pages. Published by John Wiley & Sons, New York City. Price, $2.50 net.

This volume is devoted to a descriptive treatment of modern electric lamps. Much emphasis is placed on the developments leading to higher efficiencies and the book has for its chief aim the furnishing of information on the principles of these new light sources, their manufacture, use, care and handling. The material is characterized by a mechanical as well as a physical interpretation of lamps and their operation, and is intended for the general reader and the central station man. It would be difficult indeed to make the treatment of such a variety of electric illuminants complete in detail within the confines of a single volume and, as stated in the preface, the book does not claim to be exhaustive.

The first two chapters are given to the subject of light, color, photometry and units of illumination. Three chapters follow in which incandescent, arc and vapor lamps are described at length while the two closing chapters are devoted to a descriptive treatment of interior and exterior illumination. The preface calls attention to the fact that the book "does not purport to more than generalize on the proper use of the new illuminants for various conditions of lighting, interior and exterior"; also to the fact that much of the material has been gathered from the pages of leading periodicals. Properly speaking, the text is rather a treatment of light sources than their application. Illumination has become a branch of engineering calling for exact treatment rather than generalized description, hence the book can hardly be looked upon as a reference for information on the subject of illumination design and installation. Taken as a whole this volume contains a considerable amount of useful information on electric lamps gathered from a variety of sources and placed in convenient form.

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NEW BOOKS

"Central Station Heating"—Byron T. Gifford. 5½ inches by 9 inches, 208 pages, 37 illustrations. Published by the Heating and Ventilating Magazine Co., New York City. Price, $4.00.

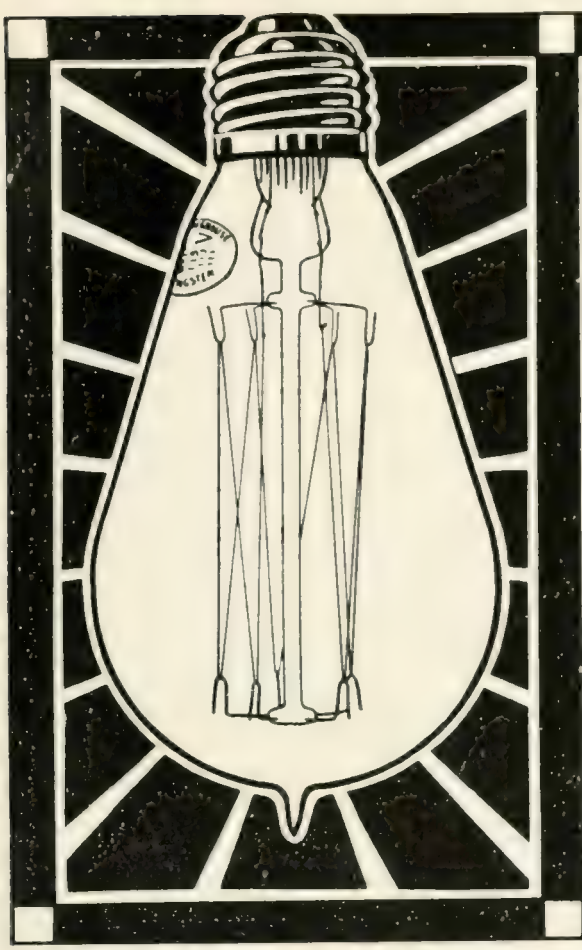
Although the central station heating industry is of long standing, there has been little extensive literature on the subject. It is a topic, too, that is not unfrequently argued alternately in a favorable and unfavorable way. A survey of the central station heating conditions such as the author undertakes has therefore much to favor it. In this book, the advantages of central station heating is first noted after which follows a discussion of the engineering features of the different hot water and steam distribution systems. The question of plant management has been given attention, as upon it the success of such an institution naturally revolves, and this has been supplemented by contingent conditions which must be understood to make the house service satisfactory. The drafting of franchises and the computing of rates has been taken up in separate chapters. Miscellaneous data which will be of use in connection with this line of work forms the tenth and concluding chapter. The author apparently confines himself largely to his own individual experience, and does not give in some cases the derivation of rules and conclusions which might have been profitably demonstrated more fully for the benefit of the reader. E.D.D.

"Electric Traction for Railway Trains"—Edward P. Burch. 585 pages, 185 illustrations. Published by the McGraw-Hill Book Company, New York. Price, $5.00.

This work, which might be termed a railway engineer's scrapbook, contains just the material which any railway engineer would desire to gather could he have a wide acquaintanceship among prominent railway engineers, free access to all technical literature and abundant time to classify and tabulate the material collected. It forms a veritable encyclopedia on the subject of railway trains. It is not intended as an elementary or popular treatise on the subject, though containing much that is of interest to the layman, but rather assumes that the reader has a working knowledge of standard steam and electric practice. The material has been limited strictly to those features which are pertinent to train operation, and does not include single car operation for either street or interurban railways. Within the limits of the subject, however, little seems to have escaped the author's attention. Operation with direct current at 600 and at 1 200 volts, with single-phase and with three-phase power is impartially discussed, bringing out the advantages and disadvantages of each system and the field to which each is best adapted. Train operation with locomotives and with motor cars, the amount of power required for train operation, types of motors and locomotives, transmission and contact lines, and power stations have been treated fully. In addition, the author has culled from the technical press and other sources descriptions of practically every railway electrification in this country and Europe, and numerous illustrations of representative railway apparatus are included. These features, together with the large amount of comparative data as to weights, size of motors and locomotives, tractive efforts, cost of installation and of operation, etc., included in the numerous tables, make the book of exceptional value as a reference work. Numerous cross references are included and the material is so arranged as to be readily accessible. Each chapter is introduced with an outline of its contents and is concluded with an exceptionally complete classified bibliography of current material on the subjects discussed. C.R.R.

"Electric Central Station Distribution Systems"—Harry Barnes Gear and Paul Francis Williams; 347 pages, 139 illustrations, 24 tables. Published by D. Van Nostrand Company, New York City. Price, $3.00.

This volume is the result of a group of articles which appeared serially in the *Electrical Age* during the years 1908 and 1909, the material having been revised and somewhat extended before publication in book form. It is not a work which will be of value to advanced engineers. It is, however, a book which should be of great assistance to students of electrical engineering, to young engineers engaged in distribution work and to those practical distribution men who are more or less thoroughly acquainted with the details of the actual work, but who wish to study the reason for the use of certain apparatus, methods of connection or systems of distribution. The treatment assumes a knowledge of electrical theory no greater than that possessed by the majority of men in either of the classes mentioned. No attempt has been made to advocate any particular system or kind of apparatus, but a discussion of



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the advantages and disadvantages of all the common types and systems is given, as it is evident that the decision in any given case must be determined by local conditions. The exceptionally wide field covered by the book may be shown by the headings of the chapters, namely: Systems of Distribution, Transmission and Conversion, Voltage Regulation, Line Transformers, Secondary Distribution, Special Schemes of Transformation, Protective Apparatus, Overhead Construction—Pole Lines, Lines and Accessories; Underground Construction, Cable Work, Distribution Economics, Properties of Conductors, and Alternating-Current Circuits.

The discussion of construction details is based upon those features which have become standard in the larger cities. All details of construction, methods of connection, installation and operation, and systems ordinarily encountered in central station distribution for cities are treated fully and liberally illustrated; the diagrams of typical distribution systems, and of standard and special transformer conections being of unusual merit. No attempt has been made to treat the special problems arising from long distance or extremely high voltage transmission. C.R.R.

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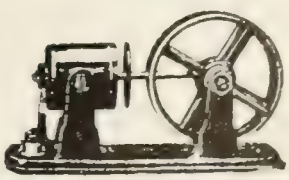
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NEW BOOKS

"Applied Methods of Scientific Management"—Frederick A. Parkhurst. 307 pages, 48 figures and 9 plates. Published by John Wiley & Sons, New York City. Price, $2.00, net.

This work is based on the series of articles which appeared in *Industrial Engineering* during 1911. The methods outlined are those which apply specifically to the Worcester Machine Company, of Bridgeton, N. J., and apply, in general to business organizations in which two or more people are employed. The methods adopted by this Company are gone into very much in detail. The principles outlined are essentially those originated by Mr. Fred. W. Taylor and his followers. The book is illustrated with numerous sample forms to be used in various ways in carrying on the different operations in a factory. Considerable space is devoted to analyses of time studies and systems of wage payment.

"Electric Ignition for Combustion Motors"—Forrest R. Jones. 148 pages, 104 illustrations. Published by John Wiley & Sons, New York City. Price, $1.00.

This work gives, in a style which can be understood by non-technical readers, very complete data on the subject of electric ignition, from the small ignition apparatus so that used on the largest gas engines. It is thoroughly illustrated by diagrams and views of commercial apparatus. It includes descriptions of various types of magnetos and batteries, of spark coils of the different ignition systems mechanically operated make and break igniters, electromagnetic igniters, timers and spark plugs for high tension ignition, primary batteries and battery connections. Chapters of special interest to automobilists are also included, such as on varying the time of ignition, care and adjustment of ignition systems, charging and care of storage batteries, correction of operating troubles in ignition systems, etc. At first thought one is apt to think there is not enough in this subject to warrant such a book, but on reading this work taking up the subject in a broad way and including the various auxiliary apparatus it becomes evident that the subject is one of considerable importance.

"The Elements of Structure"—George A. Hool. 250 pages, 230 illustrations. Published by McGraw-Hill Book Co., New York City. Price, $1.75.

This book is the first of a series of educational publications prepared in the extension division of the University of Wisconsin. The book has been developed solely with the idea of using it in correspondence study. The University of Wisconsin has been one of the first to adopt correspondence methods and its success should lead many other institutions to follow their example. It is undoubtedly very often the case that the ones who need educational assistance most are those who are not able to devote their entire time or pay their expenses at a regular institution of learning. By adopting correspondence school methods the university has been able to reach many who are anxious to improve their condition and are thus placed in touch with instructors of ability. The present book gives in an elementary way the material ordinarily found in works on mechanics under statics, bridge strains, roof trusses, etc. This book is well prepared and written in simple logical style and is provided with problems for the student's use.

Fuel Economizers at the Manhattan Power Station of the Inter-Borough Rapid Transit Company, New York City.

This is a reprint of a paper read by R. D. Homlinson before the New York Railway Club, showing by a careful analysis of tests and monthly records that the economizers in this plant are paying a neat rate of 30.5 percent upon the initial outlay. This is based upon a price of $3.00 per ton for coal and the average load at the time the economizers were put in. The output of the plant has been increased since the test was made. The plant contains 64 boilers of 520 brake hp each and the draft is produced by four brick chimneys. The pamphlet is well illustrated and should be of interest to designers and operators of large steam plants. It may be obtained by addressing the Green Fuel Economizer Company of Matteawan, N. Y.

"Wireless Telephones and How They Work"—James Erskine-Murray. 66 pages, 18 illustrations. Published by the Norman W. Henley Publishing Company, New York City. Price, $1.00.

This is an excellent little sketch in nine chapters, partially historical and the remainder descriptive of the theory and practical results obtained in wireless telephony.

THE
ELECTRIC JOURNAL

Vol. IX MAY, 1912 No. 5

The Economy of Good Commutation

The vital feature of every rotating electrical machine provided with a commutator is its behavior at that commutator. The prime requisite for satisfactory performance in this respect is excellence of design, both electrical and mechanical. This applies to brush arms, carbon holders and carbons as well as to armature windings and commutator.

The tendency in modern design is toward much higher commutator speeds than were formerly used, and with this tendency has come an increase in the length of commutators. Owing to the higher centrifugal stresses and longer bars the problem of the mechanical design of this element, always a most difficult one, has been greatly increased. It is to be noted, however, that the advent of the commutating pole, which has practically eliminated the necessity of shifting the brushes with changes in load, has simplified matters for the designer. Other refinements, such as improved grades of carbons and the practice in certain cases of undercutting the mica between bars, have also been of assistance. However, excellence in design alone, will not insure satisfactory behavior. In addition constant vigilance must be exercised by those operating commutating machines to prevent untoward conditions from arising which may vitiate the good results achieved by the designer.

In the article on "Care and Operation of Commutators" in the present issue of the JOURNAL, Mr. Dick has outlined very fully the improper conditions which tend to cause commutation troubles and has shown how to remedy them. This article should be carefully read and thoroughly digested by all users of commutating electric machinery. Every operator should understand that bad commutation means not only wear and tear of the commutator and its accessories, but also a constant money loss due to the decreased efficiency of the apparatus.

The safe load limit of the ordinary commutating machine is determined by its ability to commutate satisfactorily rather than by

the temperature of the windings. But the design of some of the modern commutating pole machines has been worked out so carefully that overloads will cause dangerous heating of the windings before destructive sparking at the brushes occurs, provided the commutator and brushes are in perfect condition. Careful attention to these parts makes for increased efficiency and for the ability to handle heavy overloads successfully.

Prospective purchasers of commutating machines often hold up negotiations for long periods haggling with rival salesmen for fractional percents of efficiency. Any saving in power thus secured is too often invalidated, once the apparatus is installed, by ignorance of the proper commutating conditions. High bars, excessive brush tension, improper setting of brushes, poor carbons and other defects are responsible for the consumption of many a foot-pound of energy, which could be saved if every operator thoroughly understood the importance of ideal commutator conditions as a factor in the production of power.

E. M. Olin

Engineering Methods in Factory Electrification

With the rapid progress in the industrial field in the last few years and the tremendous competition in all lines of manufacture it is becoming more and more necessary to look closely into every detail of possible economy in production and take advantage of every advance in engineering methods in order to place manufactured products on the market, finished to the highest possible standard of perfection, at the lowest possible cost of production. Not many years ago the equipping of manufacturing plants with motor drive was considered a luxury and as not effecting a sufficient economy in operation to warrant the initial expense. In some cases this was an actual fact; first, because very little information was available to determine power requirements, and second, because the manufacturers of electrical machinery had not advanced to their present day stage of being able to furnish motors specifically adapted by their inherent characteristics to almost every class of machine manufactured, so that by the proper selection and application of motors to meet the particular requirements a maximum efficiency of operation can be obtained with minimum cost.

To-day a large percentage of the manufacturers throughout the country use electric drive to some extent in their factories. The more progressive manufacturers realize the importance, when plan-

ning for such equipment, of obtaining the very best expert advice on the subject and not determining their requirements in the haphazard fashion formerly used. This determination often consisted solely in walking through the plant with the electrician or superintendent and deciding that they had better put a twenty horse-power motor over in one corner, which with the ten horse-power motor in the other corner would probably give them about enough power.

The selection of motors for driving machinery in any factory requires the consideration of three prime factors, which are almost equally important. These are:—First, the determination of the method of drive; second, the selection of the proper size of motor, and third, the determining of the proper characteristics of motors for each class of drive.

The method of drive should always be most carefully investigated to determine what machines should be operated by individual motors and what machines in groups from line shafts. There are many details that should be considered in deciding on this feature. The kind of machine to be driven, whether it is to be operated at a constant speed with a constant or variable load or whether speed variation and control are necessary, the sequence of operations required to obtain most efficient production of the manufactured article, the time factor and load characteristics of each machine and the load factor of the entire plant, all enter into this problem and should be carefully considered.

Having determined by a full consideration of all factors what is the best probable method of drive, it is then necessary to select the size of motors so that the average operating load will approach as closely as possible to the maximum efficiency load point of each motor. The maximum net efficiency of the entire plant is thus obtained.

Where individual drive is determined upon, the proper inherent characteristics of the motor must be determined by the operating conditions of the machine to be driven and accurate tests to determine the load curve and cycle of operation should be made. This will determine the speed variation and control needed, as well as the proper capacity, characteristics and overload rating of the motor to produce the best results. The nature of the work to be performed will also determine whether the motor should be of the open, semi-enclosed, or fully enclosed type. All of these features should be carefully studied and expert engineers should make the proper and

necessary tests to select the most suitable methods of drive and the proper type and size of motors, in order that the electrification of the factory will effect the highest economy of production at the minimum power cost. Managers of factories too often leave these matters to men in their employ who, while of high efficiency in the performance of their regular duties, have not had the experience necessary to make either a proper investigation of requirements or to select the proper equipment after the power requirements have been determined, resulting too often in the use of a system of drive which is not the best for the service demanded. This results either in the overloading of motors to their injury, the failure to operate machines under proper manufacturing conditions or the over-motoring of the plant, with a consequent reduction in efficiency of operation as well as an unnecessary increase in investment.

Economies are often made in shop methods and systems, sales organizations and office management to increase the economy, production and profits, while at the same time, either through a lack of thought or of knowledge on this important subject, the saving thus effected may be largely offset or perhaps even overbalanced by inefficient methods of operation and power application.

WILLIAM B. WREAKS

The Value of the Oscillograph to the Electrical Industry

Some interesting applications of the oscillograph are illustrated and discussed in this issue of the JOURNAL by Mr. Galleher. These particular cases are only typical of the many difficult problems which the oscillograph has solved. Great things have been accomplished in the last eight years by the use of this valuable instrument, but greater things can be expected in the future when its broader scope and usefulness become more fully appreciated.

Thanks to the oscillograph, we now know in just what time a circuit breaker opens; how quickly a relay acts; what maximum currents a motor takes in starting and during operation on variable load; exactly what instantaneous current a generator will give when short-circuited; what current surges occur when a transformer is connected to the line; whether the generator has a sine shaped e.m.f. wave; and so on, through a long list of important problems to which this instrument has supplied the answer. When it is considered that ten or perhaps fifteen years ago all these questions

merely gave rise to speculation and discussion among engineers, and no definite information regarding them could be obtained, the real value of the oscillograph to the electrical industry is more readily appreciated.

However, as Mr. Galleher points out, the uses for this instrument are multiplying rapidly. Consider the example of circuit breaker operation; at first the complete time of opening was practically all that was required. As further developments and improvements are made in circuit interrupting devices, the circuit breaker designer is no longer satisfied to know the complete time in which the apparatus operates, but he desires to know just what time is required for each of the component parts to perform its function. In the same way, the electrical machine designer, who at one time was happy if he obtained the field form or e.m.f. wave form of his machine, now must know the flux pulsations in the teeth caused by open slots in both the rotor and stator; the voltage under the brushes of a direct-current machine when the load is changed suddenly; the leakage flux in the end windings of armatures; the ripple in the field current caused by the variable reluctance of the air-gap, and a great number of similar details.

There is another reason why the oscillograph is justly popular. One of the first senses developed in man is the sense of sight. Through his eyes he is accustomed to obtain distinct and accurate knowledge of all material things. A designer likes to get his machine on the drawing board. He also likes to study the phenomena which occur in his machine by means of pictures of its performance, or oscillograms. "Seeing is believing," and there is nothing which will so quickly settle all discussion and doubt concerning what actually happens in a piece of apparatus as a faithful picture of the phenomenon itself. A photograph or tracing gives a physical conception of what actually occurs and simplifies many seemingly complicated relations. Like the telephone and telegraph, the benefits derived by the use of the oscillograph are so great that it is difficult to see how the present electrical industry could do without it.

C. E. Wilson

CARE AND OPERATION OF COMMUTATORS

W. A. DICK

The purpose of this article is to outline some of the difficulties which may be encountered in the operation of machines having commutators, and to indicate how improvements can be made in machines with which trouble is experienced, and, also, in some cases in machines which are giving reasonably satisfactory performance. The points covered will be such as pertain both to commutators and to current collecting devices used with them.

AS is well known, a commutator is made up of a large number of copper segments which must not only be held mechanically so that they cannot be displaced from their normal position, even a very small amount; but also must be insulated thoroughly from each other and from the supporting member. Mica is the insulating material universally used for this purpose. The mica segments are built up of thin mica splittings held together by suitable bonds. In operation, electric currents must pass both out of and into these commutator segments or bars through stationary conductors in sliding contact with them. The contact of these conductors or brushes must be sufficiently intimate to secure proper and continuous operation. Carbon, at the present time, is the material universally used for brushes, except in the case of some types of very low-voltage machines, where metal may be used to advantage.

With the somewhat complicated construction necessarily involved in commutators and with the very best design, workmanship and material obtainable, there are certain factors which may affect their performance under various operating conditions, the discussion of which will doubtless be of assistance to operators. For convenience the subject will be considered from the standpoints of mechanical, electrical and operating conditions.

MECHANICAL POINTS

Displaced Bars—What may be called a "seasoning out" process may take place, due to the centrifugal forces acting on the bars during operation, which causes a slight displacement of some of the bars and results in a gradual reseating on the insulation. This displacement is more apt to develop in commutators operated at the higher speeds and in large commutators with their greater number of parts. All commutators are seasoned out during the process of manufacture and test, to get the yield out of the materials, so that

there will be no displacement of the bars later. Much of this is done, before the armatures are completely assembled, by the application of heat and the tightening up of the bolts holding the parts together. The commutators are not, however, subjected to both heat and centrifugal strains until put into operation, when further seasoning may take place. This is often so gradual as to continue for a considerable period of time, especially on machines of large size. In all such cases the commutators should be tightened if loose and trued up from time to time until a permanent condition is reached, the methods to be followed in doing this being described later.

Eccentric Conditions—Commutators may run out of true due to bent shafts, spring in shafts from engine thrust or looseness in the bearings. The remedies are obvious. If the eccentricity cannot be overcome by remedying these defects turning off or grinding at normal speed as described below should be resorted to. Commutators of engine-type machines which have been machined while mounted on test shafts often run slightly out of true when pressed on the engine shaft and require turning or grinding after erection. Electrical machines require shafts stiff enough to take care not only of the mechanical strains but of the magnetic pull set up by the field magnets. Commutators if subjected to excessive temperatures from overload or defective operation may become distorted and run out of true; this is an abnormal condition and means should be found of reducing the temperatures. This heating can be caused by sparking at the brushes or excessive friction. Friction is least when commutators run true and have a high polish or glaze and the brush faces are polished.

Mechanical vibration may be set up in armatures, and is most apt to be evident on machines operated at the higher speeds, such as turbine-driven units, motor-generator sets, etc. It is usually due to a mechanically unbalanced condition of the rotors. Proper contact between the brushes and the commutator is very difficult under these conditions. It should be overcome by rebalancing. Most modern machines are provided with means for balancing either by balancing weights or pockets into which melted lead can be poured. When such means are not provided, weights may be bolted to the the rotors, care being taken to place and fasten them so that they cannot get loose. In extreme cases the commutator may be loose on the clamping rings, in which case tightening up of the bolts hold-

ing the parts together is required, and turning or grinding may then be necessary.

High Mica—The mica between the commutator bars may not wear quite as fast as the copper, so that the mica segments eventually project above the copper. This condition is most apt to appear in commutators having a relatively large number of bars which are therefore comparatively thin; it is evident that in such designs the percentage of mica is high as compared to the copper. The amount that this mica extends above the copper may be very slight and still be enough to prevent full and complete contact of the brushes with the copper bars. High mica can usually be detected

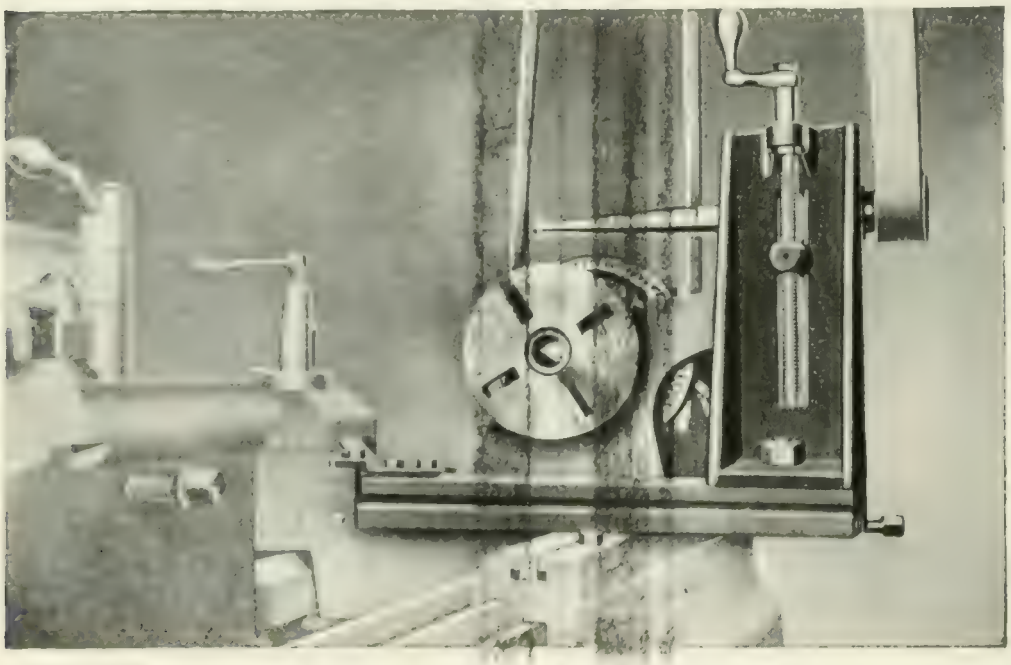


FIG. 1—Tool for undercutting commutator mica, attached to a lathe and driven by a belt. Armature is placed between the lathe centers. Manufactured by Charles N. Wood Company, Boston, Mass.

by mechanical inspection. Results of this condition are likely to appear as fine pin sparks between the faces of the brushes and the commutator, and also the copper is blackened and burned. The very best obtainable grades of soft commercial mica used for insulation are known to vary somewhat in hardness, which probably results in variations in the hardness of the built-up segments. A more frequent cause of high mica is believed to be found in the increasing use of softer grades of carbon brushes such as have recently been developed which have less abrasive material in their composition to better meet other conditions of commutation.

Undercutting There is an increasing tendency on the part of both operating and manufacturing companies to resort to the cutting down of the mica between the bars as a means of eliminating any possibility of trouble due to high mica. In some classes of machines, such as single-phase commutator type motors, turbo-generators and special applications, this undercutting is necessary.

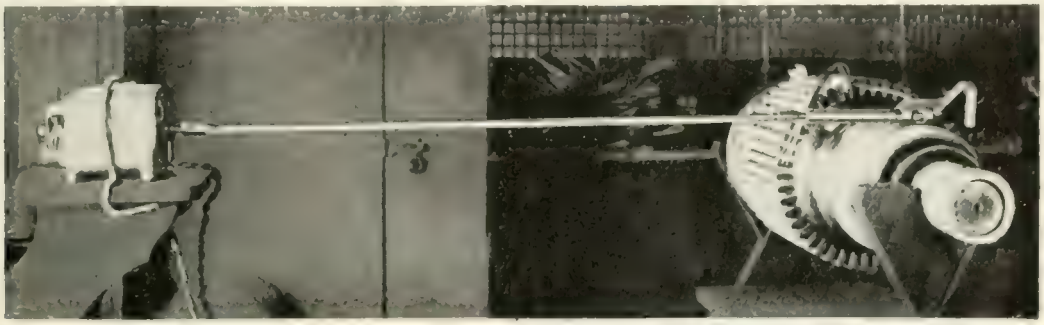


FIG. 2—PORTABLE TOOL FOR UNDERCUTTING MICA, DRIVEN BY AN ELECTRIC MOTOR
Armature can be set in any convenient place or tool can be taken to the armature.
Railway & Industrial Engineering Company, Pittsburgh.

The undercutting results in better brush contact, eliminates burning due to high mica, improves commutation, thus increasing the life of commutator and brushes, and may reduce the temperature and increase the capacity of machines not limited by temperature rise of other parts. Its general effect is to improve operation. It should be noted that sometimes undercutting may involve a change in the grade of brush to be used to secure best results.



FIG. 3—MOTOR DRIVEN PORTABLE TOOL FOR UNDERCUTTING COMMUTATOR MICA
General Electric Company, Schenectady, N. Y.

The undercutting may be done by a tool equipped with a thin saw or milling cutter driven by an electric or air motor. Devices in use for this work are shown in Figs. 1, 2, 3, 4, 5 and 6 inclusive. A hack saw blade with a backing for stiffening and holding makes a satisfactory hand tool. A hand chisel may also be used with a straight edge for a guide. The surface of the copper forming the

sides of the slots should be left smooth, and at the sharp edges the bars should be slightly rounded. A saw about one inch in diameter, having 30 to 40 teeth and run at a speed of about 2 000 r.p.m., meets the average conditions satisfactorily. With very hard mica a saw with a greater number of teeth will cut a little better. A thickness of saw about 0.003 inch less than the width of the slot to be cut will give the right width as the teeth usually have a slight set.

Usually the undercutting must be repeated after the machines have been in service for some time, but is required at only very infrequent intervals. The usual depth of undercutting is one-thirty-second inch and should not be over one-sixteenth inch. The slot should not be less than one-thirty-second inch in width. The objection to a narrow or deep slot is the increased liability of accumu-

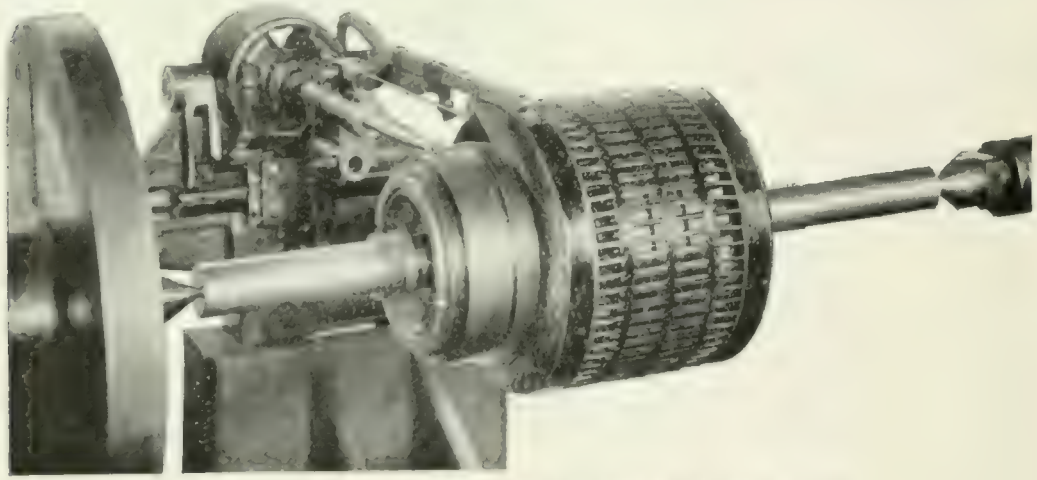


FIG. 4—TOOL FOR UNDERCUTTING COMMUTATOR MICA
Attached to a lathe and motor driven.
Westinghouse Electric & Mfg. Company, Pittsburgh, Pa.

lation of dirt and consequently greater difficulty in keeping the commutator clean. The only trouble that can result from the cutting down of the mica is an accumulation of material in the slots, which of itself, or by holding carbon or copper dust, forms a circuit between adjacent bars. The centrifugal forces of the machines on which undercutting is commonly done are sufficient to throw out any ordinary accumulation of dirt. A small amount of care and attention and, if necessary, cleaning, will suffice to prevent any dirt accumulation. It is accordingly advisable to make slot inspection and cleaning a part of the regular care of the machine.

ELECTRICAL POINTS

Wrong Brush Position—The brush position on all commutator type machines is important and on all such machines there is a best

position, variation from which may result in sparking. Brushes may have the wrong position by not having the proper location, or lead as it is called, on the commutator. A brush is given a lead when it is shifted from the so-called neutral or mid position. The lead is said to be forward when the brushes are shifted with the direction of rotation, and backward when against the rotation.

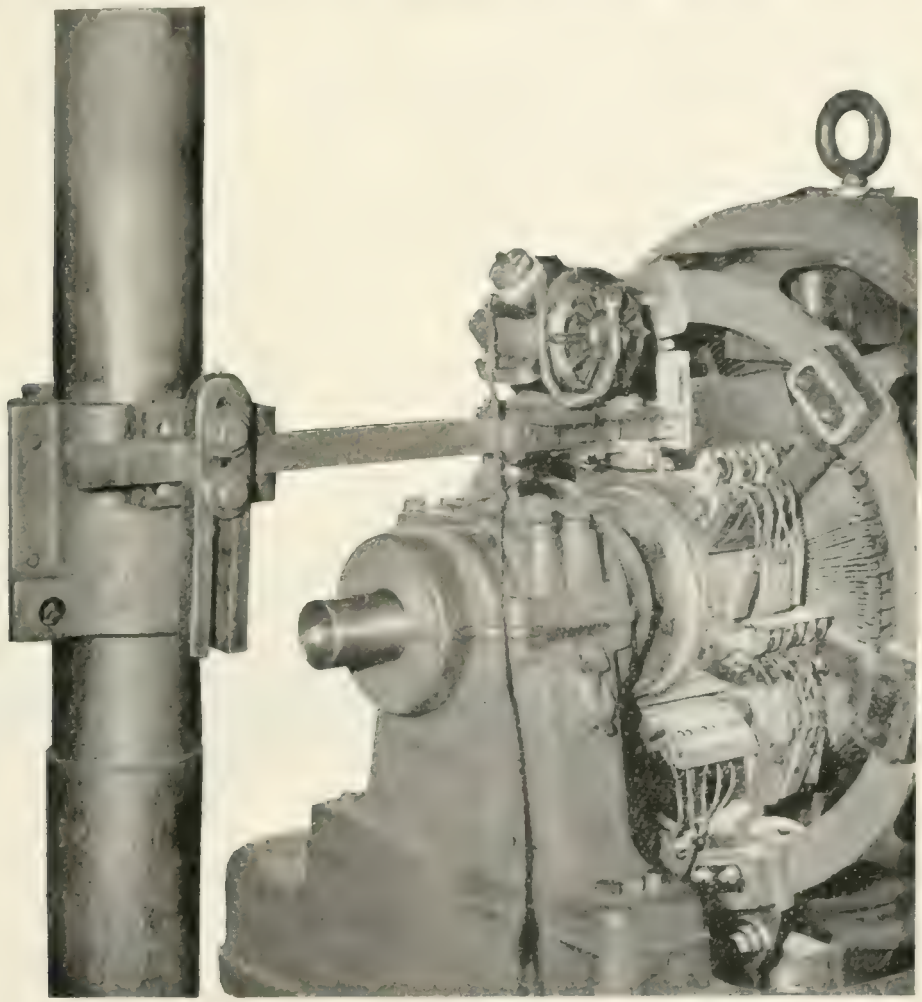


FIG. 5—MOTOR DRIVEN PORTABLE TOOL FOR UNDERCUTTING COMMUTATOR MICA

Note piece of fullerboard placed in front of the commutator necks to keep chips from getting into the armature. This is an important precaution.

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They may also have the wrong position through uneven spacing around the commutator of the arms carrying the brushes, as a result of which some of the brushes are given the right lead and some the wrong lead. Accurate and uniform spacing is essential. It is also possible for a brush arm to be so shifted that the brushes are out of line with the bars. Machines with commutating poles

have a fixed point of commutation with which satisfactory operation is obtained over wide variations in load.*

Attention is called to the fact that in non-commutating pole machines the armature reaction tends to shift the field set up by the main poles, as the load varies. As the brushes are given a lead in order to have an active flux from the poles of sufficient value to reverse the current in the coil undergoing commutation, it follows that, although the machine operates with a fixed brush position, the reversing flux in the coil undergoing commutation actually changes somewhat as the load varies. It can be noted, therefore, that better operation with lower losses will result if, on non-commutating pole machines, the brush position can be changed with the load by shifting, and that an advantage is gained by so doing where conditions permit, with results that more than warrant the small amount of

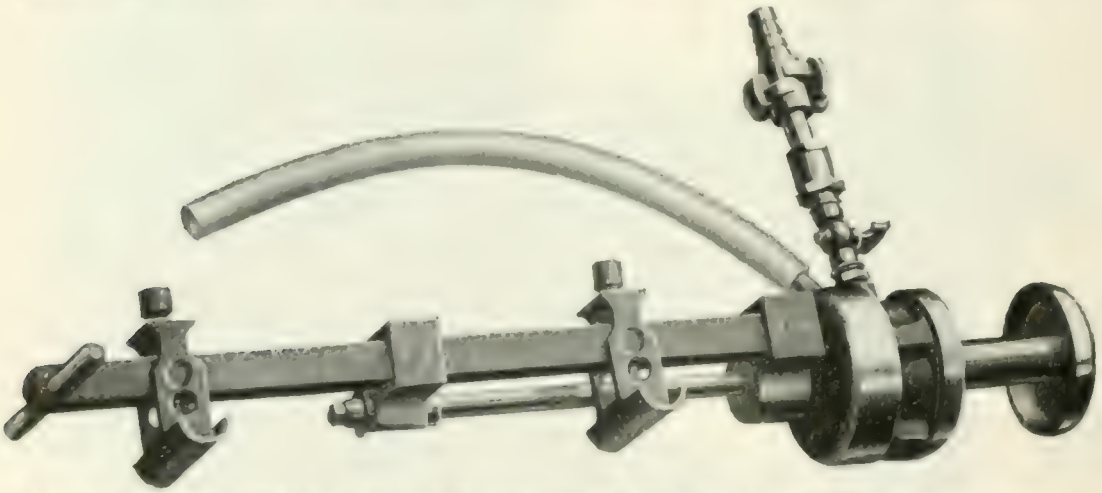


FIG. 6—SMALL PORTABLE TOOL FOR UNDERCUTTING MICA, DRIVEN BY AIR MOTOR
Westinghouse Electric & Mfg. Company, Pittsburgh, Pa.

attention required for this purpose. In commutating-pole machines a commutating flux in a fixed position is provided by means of additional poles on which are windings connected in series with the armature, and as this commutating pole flux varies directly with the load no brush shifting is required. The brushes must be set at the proper position provided for them by the commutating poles, and not changed from this position. In fact shifting from this position is liable to result in sparking.

Local Roughness from Excessive Current—Sometimes a sudden and very heavy overload, such as a short-circuit on the line, will cause the current to "bite" into the copper at certain points and

*See article on "Operating Characteristics of Commutating Pole Machines", in the JOURNAL for Dec., 1911, p. 1066

leave a condition of roughness. If this roughness is slight, it may wear away with continued operation of the machine. If severe, it may not do so, but may become worse and spread around the commutator. The remedy is to have the commutator smoothed up as soon as possible by working the spots down with a fine file or by means of sandpaper. A flash-over will sometimes make a flat spot on a commutator which will need to be taken out to prevent burning.

Local Roughness from Periodic Loads—With results somewhat similar to those referred to in the previous paragraph, but at a much slower rate, roughness may come on commutators operating on a periodically varying load, as with a gear or other drive such that the maximum load comes repeatedly at the same point in the revolution of the armature. Such combinations are found in motors geared to reciprocating pumps, air compressors and the like. Thus one part of the commutator is continually worked harder than the rest. This may result in slight burning at this point and, if not watched and kept in good condition, it may extend itself around the commutator. The gear ratio may, however, be modified so as to avoid this. A fly-wheel is sometimes used to smooth out the peaks and thus keep the current more nearly constant.

In a somewhat similiar way, anything that causes poor contact at one point on the commutator throws current to the other brushes of the same polarity, thereby causing them to be overloaded. This may result in burning of the commutator under the overloaded brushes at the time of overload, or it may burn away the brushes or both. The burning may extend around the entire commutator if the cause of the trouble is not removed. Such a condition will manifest itself, at first, in markings on a few bars, usually at a number of points equal to the number of pairs of poles. An illustration of this is the case of a generator driven by an engine in which a lateral movement of the armature takes place coincident with the crank effort. Cases have been known where a bad splice in a belt has caused a local burning. Some forms of brush holders lend themselves to this, for example, where the area of contact of the brush is changed in case of eccentric action of a commutator. Brushes may become overloaded due to part of the set becoming clogged in the holders so that they do not make contact with the commutator. This overloads the rest so that they gradually burn. Unequal brush tension may also give an unequal loading of the brushes. Some of the shunt connections between the brushes and

brush holders may make poor contact either with the brush or with the holder, and throw an excess of current to the other brushes. The remedies in these cases are obvious.

An overloaded brush may be detected by sparking; by glowing, in which spots are heated to incandescence; by honeycombing, in which spots in the face of the brushes appear to be eaten out, or by picking up of copper, where copper appears to be deposited electrolytically in spots on the face of the brush. Honeycombing often starts at these spots of copper due to localizing of the currents. Brushes may be overloaded not only by the external currents, but also by local currents passing between different brush arms due to wrong brush position or too high voltage across the brush. A change in grade of brush will sometimes improve operation where other things fail. Where a brush glows, a softer brush of higher conductivity may often be applied with good results.

Armature Conditions—An open-circuit in the armature winding, a bad joint in the winding, or a short-circuit, either in the winding or between adjacent commutator bars, will cause burning which will start at the bars connected to the defective coils. The open-circuit will make itself evident by sparking at the brushes. With a bad joint, the sparking may not always be so much in evidence, but a gradual blackening will take place. The short-circuited coils will roast out and will be liable to damage adjacent coils. Repairs should be made as soon as possible. In case of short-circuited coils where it is very important to keep the machine in operation until full repairs can be made, it is possible to cut one of the leads of the short-circuited coil and attach a jumper to the commutator bars to which it was attached.

Occasionally a case is found where the mica segments between the bars show pitting or eating out of the mica in spots. It is generally considered that this starts from some form of dirt getting on or into the mica segments. This dirt is more or less of a conductor and current carried by it, due to the voltage between bars, may sooner or later burn the mica so that it in turn becomes the conductor. This process of carbonizing or burning goes on sometimes until holes of considerable size are produced in the mica. Oil is a common vehicle for transmitting or holding the dirt and care should always be taken to see that oil does not get to the commutator insulation by creepage, spraying or otherwise.

A successful method of treating holes in the mica is to clean them out thoroughly, removing all burned and conducting material,

and then fill them with some form of high grade cement. For example, that used by dentists for filling teeth is good. Prepared chalk or plaster of paris, with sufficient shellac for a bond, has also been used; another filler may be made by mixing waterglass and powdered glass. The filling material should be made into a thick paste, applied in a workmanlike manner and allowed to set thoroughly before the machine is used. The success of such treatment depends in a large part on the care with which the work is done. Special preparations for this purpose have been placed upon the market by dealers.

Sparking at the end of a commutator is probably due to dirt of some kind. The end of the commutator should be thoroughly cleaned and then painted with a good insulating paint or varnish, and repainted as often as necessary. The outer and inner corners of the commutator should be slightly rounded as shown in Fig. 7 *a*, and should be kept rounded as the commutator wears, as it is found that a sharp corner is much more apt to pit, as indicated by Fig. 7 *b*. All the surfaces should be kept scrupulously clean.

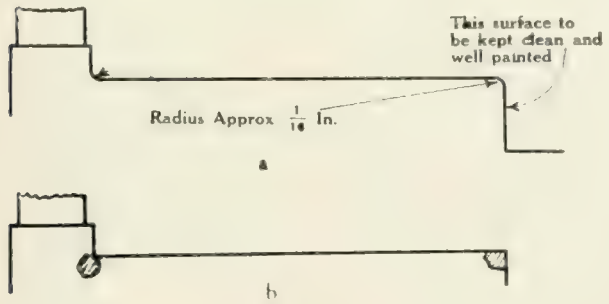


FIG. 7

a shows how the corners should be rounded when turning a commutator; *b*, the way the mica may burn if corners are not rounded.

Field Conditions—Machines may be operated under abnormal conditions as regards field excitation. For example, the operating speed may be higher than that for which the machine was designed; the operating voltage may be lower than normal, or both. The effect of these conditions is to weaken the exciting field. In commutating pole machines this should have no bad effects as the proper commutating field is maintained by the commutating poles. In non-commutating pole machines, however, the weaker field results in a shifting of the point of commutation with change of load. This will affect commutation and may cause sparking, but the trouble may be stopped by decreasing the load, shifting the brushes as load varies, reducing the speed or raising the voltage.

Brush Conditions—Some of the conditions affecting the brushes have already been mentioned. There are still other

features, however, which should be given consideration. There are numerous grades of brushes obtainable which have been developed to meet the various requirements of voltage, speed or other operating conditions. In general the manufacturer furnishes the brush best suited to any particular machine. There may be cases, however, where the particular operating conditions are such that, for most satisfactory results, a brush of certain definite characteristics is needed; such cases usually require actual trial to determine the most suitable grade of brush. A brush may collect the current very satisfactorily and yet lack lubricating qualities which will enable it to operate without chattering. The remedy in such cases may be the use of a different brush with better lubricating qualiites or what is often simpler, the occasional application of a little lubricant to the commutator.

In general it will be found that a very small amount of clean, oil is the most satisfactory lubricant to use, except in case the mica is undercut, when it is not advisable to use oil. Care should be taken to see that the oil is applied with a cloth or other material, the fibre of which will not be abraded. The good effect of a lubricant may be largely overcome by fibres of the material with which it is applied getting under the brushes and preventing good contact. For this reason, waste and felt are very poor materials to use. One of the best is a short length of cotton hose which is tightly woven. Heavy canvas is also good. Oil is a better lubricant than wax, because it works irrespective of the temperature of the commutator, while wax requires sufficient temperature to melt it. If not sufficiently softened it will gum up the commutator and cause poor brush contact; it is, therefore, not good for cool running commutators. A tendency for some brushes to smut a commutator can be overcome by an occasional cleaning with a pad moistened with a little kerosene oil. A tendency in brushes to chatter may sometimes require changing the angle of the brushes or the relation of the angle to the direction of rotation. The mounting of stiff braces between the frame of the machine and the outer ends of brush-carrying arms is of material assistance in preventing vibration.

Brush holders in the different arms should be staggered or placed out of line with each other so that the paths of the brushes on the commutator will overlap. This materially reduces the tendency to unequal wear of the commutator surface. If the commutator wears in ridges, the effect of any change in the position of

the armature in the field, such as may be found to occur with variation in load, will be to change the position of these ridges with reference to the brushes, and thus raise the brushes and prevent good contact; beside staggering the brushes, an oscillation of the armature back and forth will help in securing uniform wear. Many machines have a natural oscillation set up by the prime mover, and a continually varying load may also serve to start oscillation; however, it is becoming the practice to furnish oscillating devices for machines of large size where applicable. They give uniform oscillation back and forth irrespective of load. Rotary converters and motor-generator sets are the types usually so equipped.

Some grades of brushes, while giving very good results in operation after a polish is obtained, may not produce a satisfactory polish on the commutator when the machine is first started. It is a common practice, in such cases, to run a short time with brushes that will produce a polish and later change to the other.

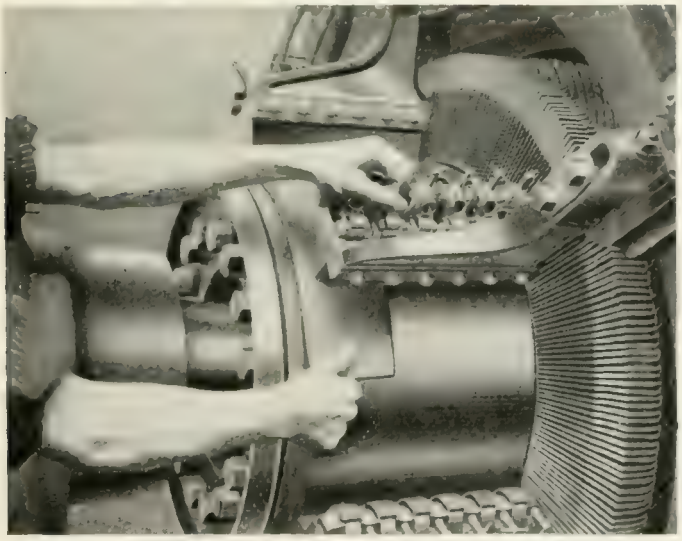


FIG. 8—SHOWS METHOP OF GRINDING BRUSHES TO FIT COMMUTATOR

The copper plating on brushes should be kept trimmed back so that it will not make contact with the commutator. The matter of fit of brushes in holders where box type holders are used is important. An easy sliding fit is best. Too great looseness allows vibration or chattering. Too tight a fit prevents the brushes from moving in the holder and making proper contact with the commutator.

The face of the brushes should have the same curvature as the commutator and be ground to a good fit with it. This can be done by placing a piece of sandpaper on the commutator so that it does not round the corners of the brushes. The operation of grinding the brushes on a direct-current machine to fit the commutator is illustrated in Fig. 8.

The amount of spring tension or pressure to be applied to a

brush to hold it in contact with the commutator varies over a wide range. It depends on speed of commutator, kind and size of brush, nature of service, etc. No definite rule can be laid down. In general it should be the minimum that will give proper results. It ranges from about six pounds per brush in railway motors to two pounds in ordinary slow speed machines, and much less on very small machines. The greater the pressure on the brush the greater will be the friction loss. The total loss at the commutator may, however, be less with heavy pressure and good contact than it is with light pressure and poor contact.

Noise from commutators is usually due to "squealing" or chatter of the brushes because of dryness of the contact surfaces. It is stopped by lubrication, changing the angle of brushes or by use of self-lubricating brushes. The matter of brushes, brush position, and brush adjustment does not always receive the careful attention it deserves, as material improvements are sometimes effected by comparatively small adjustments.

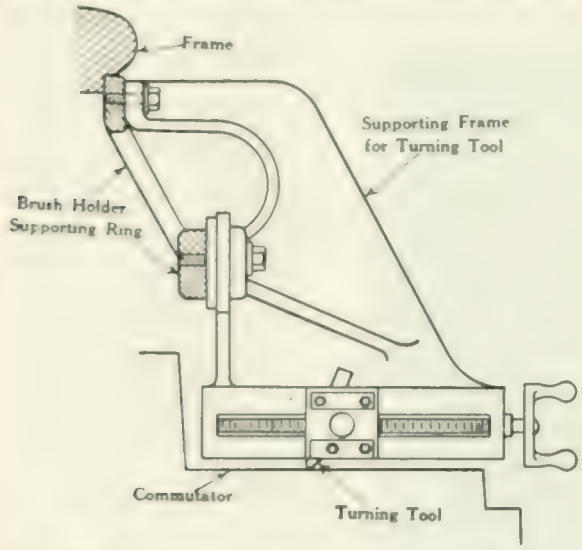
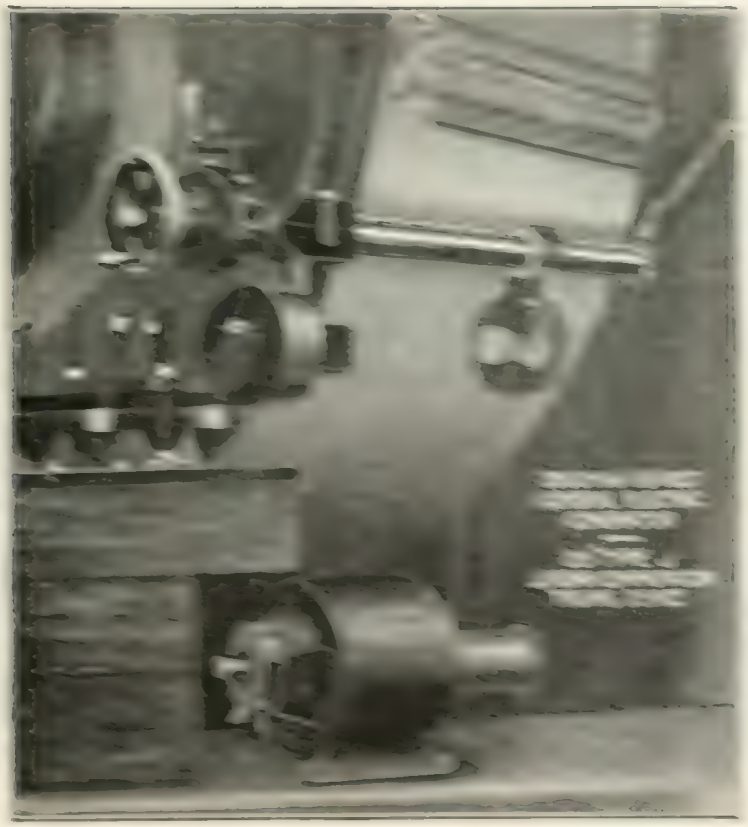


FIG. 9—COMMUTATOR TURNING TOOL.
Westinghouse Electric & Mfg. Company, Pittsburgh, Pa.

GENERAL OPERATING POINTS

Special applications may bring adverse conditions requiring special care and attention on the part of the operators of machines. Thus, for example, apparatus installed in dusty places, such as cement plants, requires frequent cleaning. Again, chemical plants are often found to produce fumes that attack the copper commutators of machines, forming a coating on the copper which is more or less of an insulator. The remedy in such cases is to exclude the fumes from the power house or resort to constant cleaning. Installations in damp places call for special attention and care. Other cases bring their own special problems.

Truing Up—There are several ways in which a commutator may be trued up. If the roughness is slight, sandpaper on a wood block of proper curvature will often be sufficient to smooth up the surface. One defect of sandpaper, however, is that from its yield-



lar lathe tool, the armature being turned at a proper cutting speed, say, from 500 to 600 feet per minute. Such an arrangement is indicated in Fig. 9. In the case of higher speed machines, it has been found that often a commutator which has been turned true at a low speed may not be perfectly true at normal speed because of slight disturbances that take place in the bars due to the centrifugal forces present at the high speeds. For this reason it is becoming more and more the practice in such cases to true up the commutators at their normal speeds, accomplishing the work by grinding the commutator

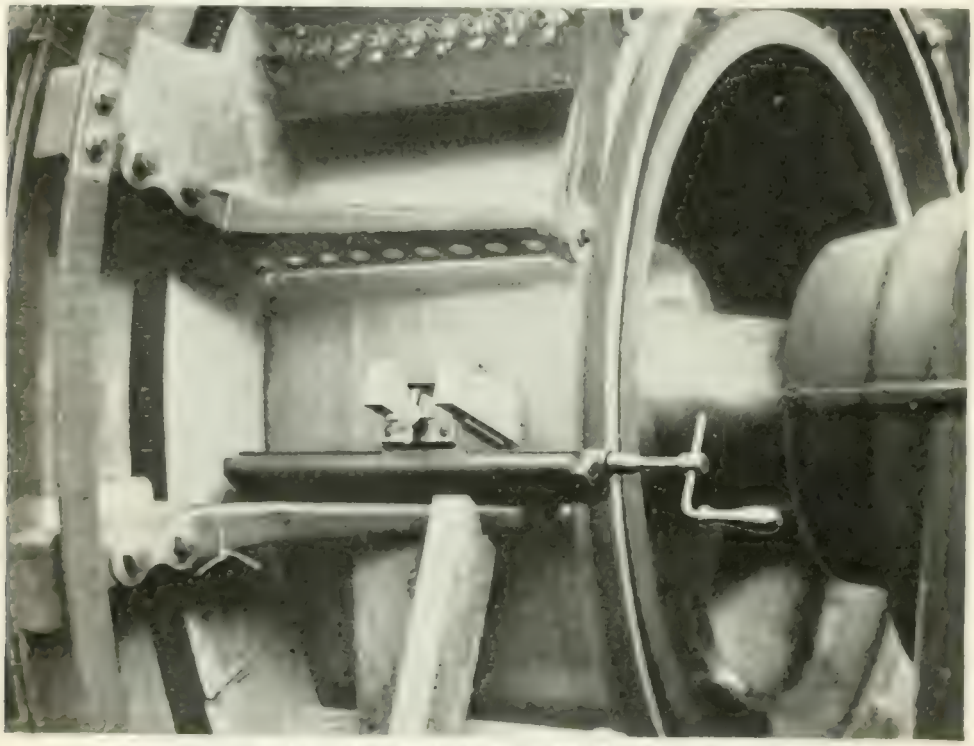


FIG. 11.—GRINDING STONE FOR TRUING COMMUTATORS

The abrasive material in the form of blocks is moved across the face of the commutator while it is turning at normal speed. Note ring of rubberoid to front of commutator serves to keep chips from getting into armature. This is especially important when machines are run at normal speed.

Westinghouse Electric & Mfg. Company, Pittsburgh, Pa.

with a suitable form of truing device. The grinding tool is provided with a guide so that it can be moved across the face of the commutator. Two types are in use, one in which the abrasion is produced by a rotating wheel of some abrading material, as shown in Fig. 10; the other, where the abrading material is held stationary, and a sandstone, emery or carborundum block is used, as illustrated in Fig. 11.

Polishing a Commutator.—A commutator under normal operating conditions should soon acquire a polish or glaze. In most in-

stances this will come in regular operation. Occasionally a case is found where this polish does not come so readily. It can usually be produced by running the machine without load and occasionally lubricating the commutator with a little oil. Temporarily increasing the brush tension will hurry the operation. In polishing a commutator just after it has been turned or ground, it may be found that free particles of copper are collecting on the faces of the brushes. If so, they should be removed. This picking up of copper should disappear when the commutator has attained a polish. A different condition of picking up copper by the brushes sometimes occurs in operation, due to electrolytic action, as a result of which they become honeycombed; this was discussed under "Local Roughness from Periodic Loads." This may or may not cause trouble. Sometimes removal of the copper may be sufficient. In bad cases a change in type of brush overcomes this action.

It is sometimes found, particularly where commutators operate at high speeds, that the brushes break or split more or less completely in their boxes; this is due to some unevenness of the commutator which strikes the brush a small hammer blow at every revolution. Sometimes this unevenness may be very apparent, again the commutator may have a high polish and appear to run true. It will be found, however, that some irregularity exists even though it be very slight. Brushes will break from a series of minute blows. In such cases a grinding of the commutator at normal speed is the best means of stopping the trouble.

The greatest enemies of electrical apparatus are moisture and dirt of all kinds, and no class of apparatus pays a larger return in improved performance and life for good care and attention. It is hoped that the present outline of the factors involved in the care and operation of commutator type machines will be of assistance in securing the best possible performance.

NEW DEVELOPMENTS IN STEAM TURBINE ENGINEERING (Concluded.)*

EDWIN D. DREYFUS

EXTENDED UTILITY OF THE TURBINE THROUGH PERFECTION OF THE LARGE REDUCTION GEAR

Use of reduction gears in turbine work dates back to the introduction of the De Laval turbine in 1880. These, however, were of small size and of the solid-bearing type. Where the power transmitted becomes of any magnitude, with dimensions correspondingly increased, the minute errors in gear cutting may greatly magnify or intensify the unit pressures on the teeth with excessive wear or fracture resulting. A compensating element must then, necessarily, be provided. The development of the Westinghouse reduction gear, which was instituted in 1904, has had for its essential feature the carrying of the pinion in a floating frame which prevents the concentration of abnormal pressures at any one point by automatic re-adjustment of its position.†

The important structural and operating features may be understood from the following summary:—

1—Self-aligning, hydraulically-supported floating frame for pinion.

2—Pinion frame pivoted at center bearing on fulcrum, permitting small oscillations.

3—Hydraulic pressure in cylinders a measure of the power transmitted.

4—Spray lubrication for gear teeth.

5—Divided helical gears cut right and left-hand, neutralizing end thrust.

6—Teeth of gear cut in special steel rim mounted on spindle.

7—Depth of mesh easily regulated by hand adjustment.

8—Flexible driving shaft extending through hollow pinion.

9—Flexible disc coupling to turbine.

A detail section through the pinion and floating frame is given in Fig. 21, and the gear and pinion with cover removed is shown in Fig. 22. The most interesting feature of the gear lies in the means provided for preserving line contact of the teeth and the automatic adjustment of any slight wear which may occur. This is done by

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*A paper read before The Western Society of Engineers, Chicago, March 4, 1912. In the first installment of the article in the April issue this acknowledgment was inadvertently omitted.

†This gear has already been described in a preceding article by Mr. H. E. Longwell in the JOURNAL for January, 1912, and its details, therefore, will be treated only in general here.

carrying the pinion shaft in a three-bearing frame, supported by hydraulic pressure cylinders beneath each boring. The frame itself is rigid and is split horizontally to receive the pinion.

On the lower side of the pinion frame, and cast integral with it, are the three cylinders above referred to and into which project short stationary pistons resting upon planed pads of a girder cast into the gear frame. Oil pressure is led to the space over the upper surface of the pistons through passages cored out in the pinion frame, and which communicate with all three cylinders, establishing uniform pressure. Hence any inequality of tooth bearing pressure would be conveyed to the pistons and thus instantly neutralized.

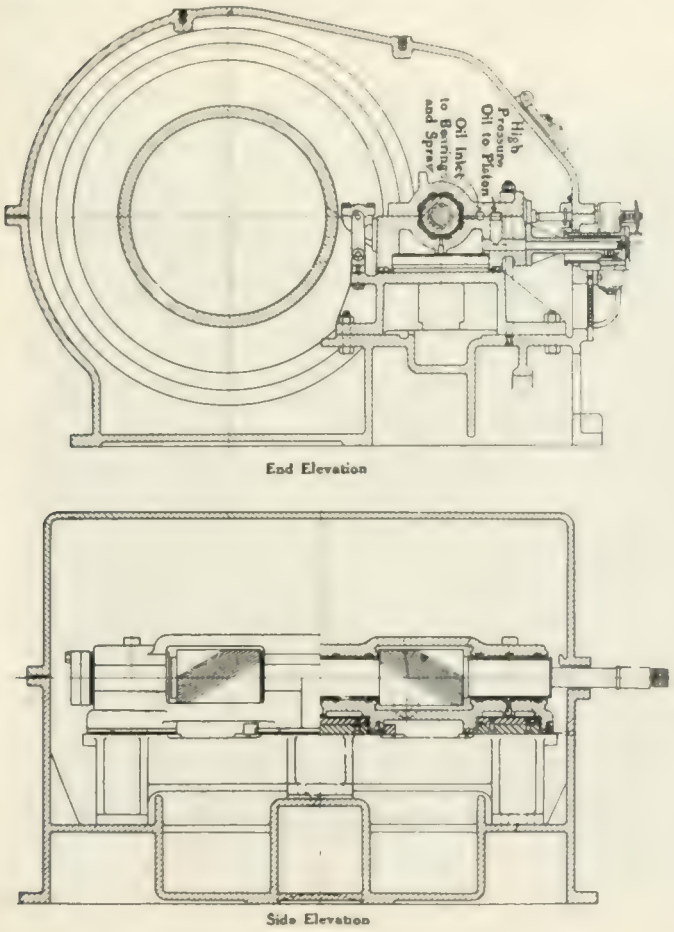


FIG. 21—SECTION THROUGH PINION AND HYDRAULIC FLOATING FRAME, HIGH POWERED REDUCTION GEAR

The prominent use of the geared turbine will be in connection with large direct-current generators, centrifugal pumps, slow speed propellers and rolling mill trains.

Direct Current Service—While there have been many large direct-coupled direct-current generators built, especially abroad, such skillful attendance is necessary that they cannot be, so far, termed a complete mechanical success. There is no room for argument that the best efficiency is sacrificed by a compromise in the design of the two elements, and this plainly opens up a large field for the geared unit. Contrary to ordinary expectation, the length of the complete direct current unit is not increased in placing the gearing between turbine and generator, principally for two reasons:—First, the length of the high-speed turbine is much less than a lower revolution machine of equal capacity, and second, a high-

speed, continuous-current generator for direct coupled units, requires a long, slender commutator. Direct-current geared units as large as 1 000 kw are now successfully operating in railway service with a turbine speed of 3 600 r.p.m. An installation view of a generating set of this type, appears in Fig. 23.

Centrifugal Pumps.—Undoubtedly further use will now be made of the large turbine-driven centrifugal pumps by reason of advances in economy resulting from the introduction of the reduction gear. Direct drive has, however, been applied to this class of service, an example of which may be found in a municipal pumping plant in Canada where two 1 125 horse-power, 1 500 r.p.m., tur-

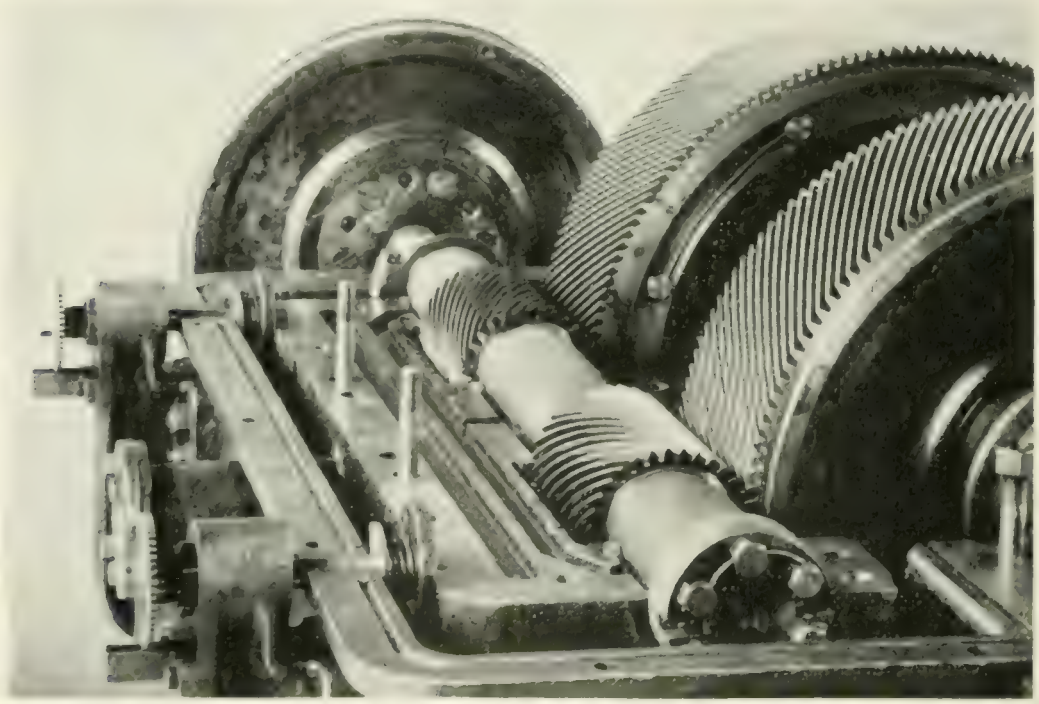


FIG. 22.—REDUCTION GEAR WITH COVER REMOVED
Showing pinion in floating frame.

bines were installed in 1906. Another installation of this kind was made comprising a 650 horse-power, 1 800 r.p.m., turbine and centrifugal pump. The latter did not experience a very large measure of success owing to the high speed employed, and accordingly has since been removed, a generator being substituted for the pump and an electrical load supplied.

An interesting installation of a pumping unit having a reduction gear interposed, has been in operation for some time in an Eastern steel mill. A view of the unit installed is given in Fig. 24. The pump is driven by a low-pressure turbine, as this application was the most profitable use to which the surplus exhaust steam could be turned. A reciprocating pump, under the existing condi-

tions, would obviously have worked in very poorly. Well-designed triple expansion engines ordinarily have a duty of 150 000 000 foot-pounds* per 1 000 pounds of steam (150 lbs. pressure dry-saturated) while the direct-coupled turbine and pump may show only about half as good a performance as that of the reciprocating type.

The 750 horse-power low-pressure outfit here shown, when operating with 27 inches vacuum, has a guaranteed duty of 52 074 000 foot-pounds per 1 000 pounds of dry saturated steam supplied at a pressure of 15 lbs. absolute. The pump is designed for an efficiency of 75 percent and the gear is included at 97 percent,

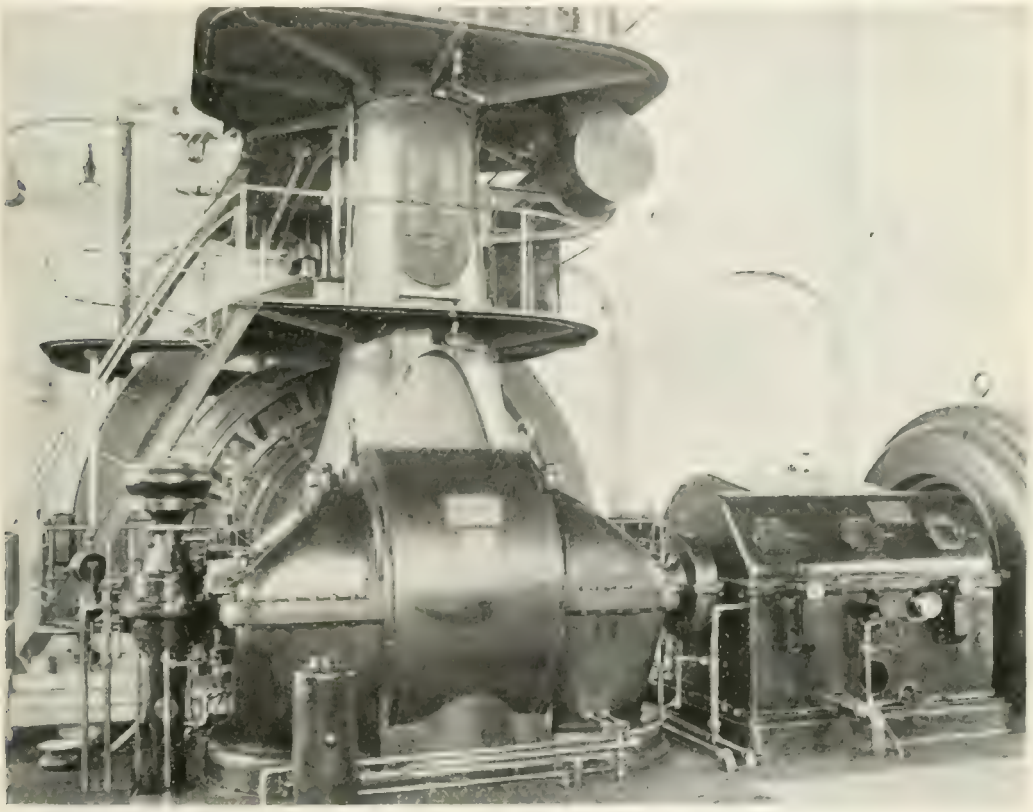


FIG. 23—1 000 KILOWATT DIRECT-CURRENT GEARED UNIT
(San Diego Street Railway Company.)

a water-rate of 28.6 lbs. per brake horse-power having been used in determining the above duty. With a complete expansion turbine driving through a gear, the combination would attain a result of about 110 000 000 ft.-lbs., and likely 120 000 000, or better, with a greater pump efficiency, an interesting approach to the triple expansion unit above noted. In cases where the pumping equipment is to be operated intermittently, the commercial economy of the geared turbine set should become superior owing to its lower first cost and repair charges, considering its inherent simplicity as com-

*Highest record with superheat, reheating and steam jacketing, 184 476 200 ft.-lbs. Philadelphia pumping station.

pared with, for instance, the vast number of small deck valves employed on the reciprocating unit.

Marine Application—Turbines were first introduced in marine vessels in 1894 when the *Turbinia* was so equipped. The trials of this ship pointed definitely to the practicability of the turbine for this service and the results have been so favorable that there have been installed to date, an aggregate of over 6 000 000 horse-power of turbines in marine service, embracing all classes of war vessels, merchant marine and pleasure yachts.

It should be noted that in the impressive capacity represented by marine installations, all turbines have been direct coupled to

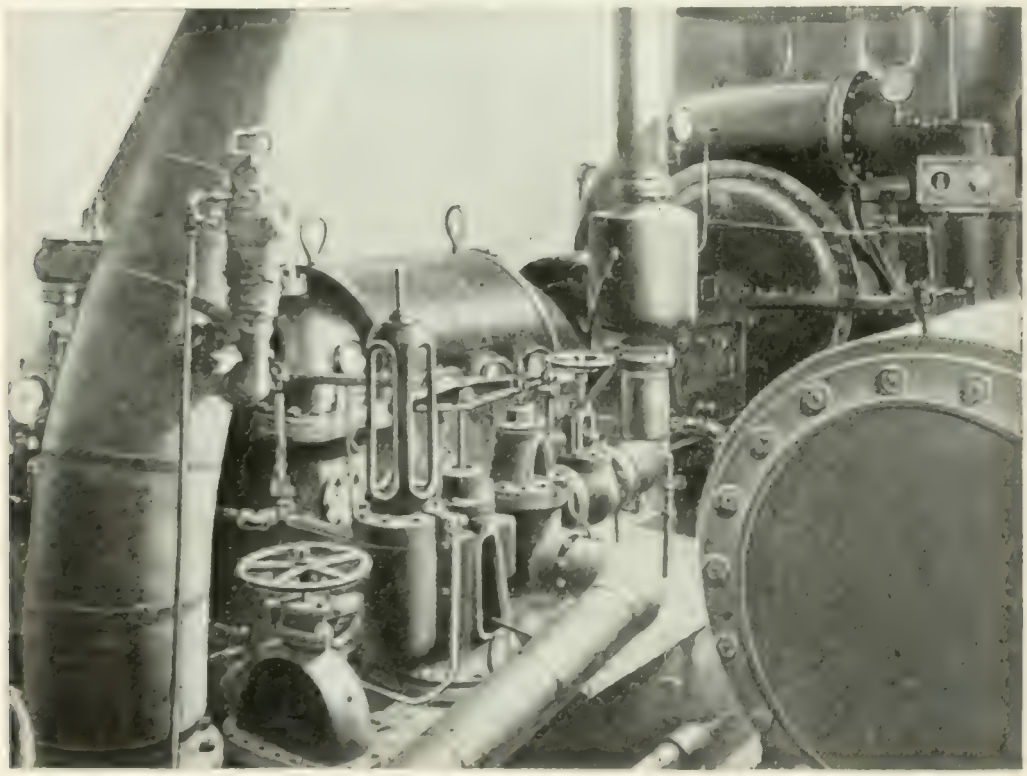


FIG. 24—LOW PRESSURE TURBINE AND PUMPS WITH REDUCTION GEAR INTERPOSED, INSTALLED IN DEEP PIT

the propeller shafts, with possibly one or two exceptions. Notwithstanding the remarkable recognition already accorded the marine turbine, it must be acknowledged that the turbine has in these cases, been installed under a disadvantage. Again there is a compromise of speeds between that of the turbine and propeller, such that their designs and efficiencies are prejudiced when direct coupled. It is not surprising, therefore, that the experience of the U. S. Navy Department has not come up to expectations. Records show that propellers for engine and turbine driven vessels have developed co-efficients of 65 and 53.8 percent respectively, evi-

dently handicapping the turbine where direct drive is employed, and little if any has been gained in weight, space and efficiency owing to the bulk and poor steam distribution required by the low speeds. Space will not allow of a more critical discussion of the subject at this time, but the reasons before cited show that we may with surety look forward to the marine turbine being given a new standing and fresh impetus through the interpolation of the reduction gear.

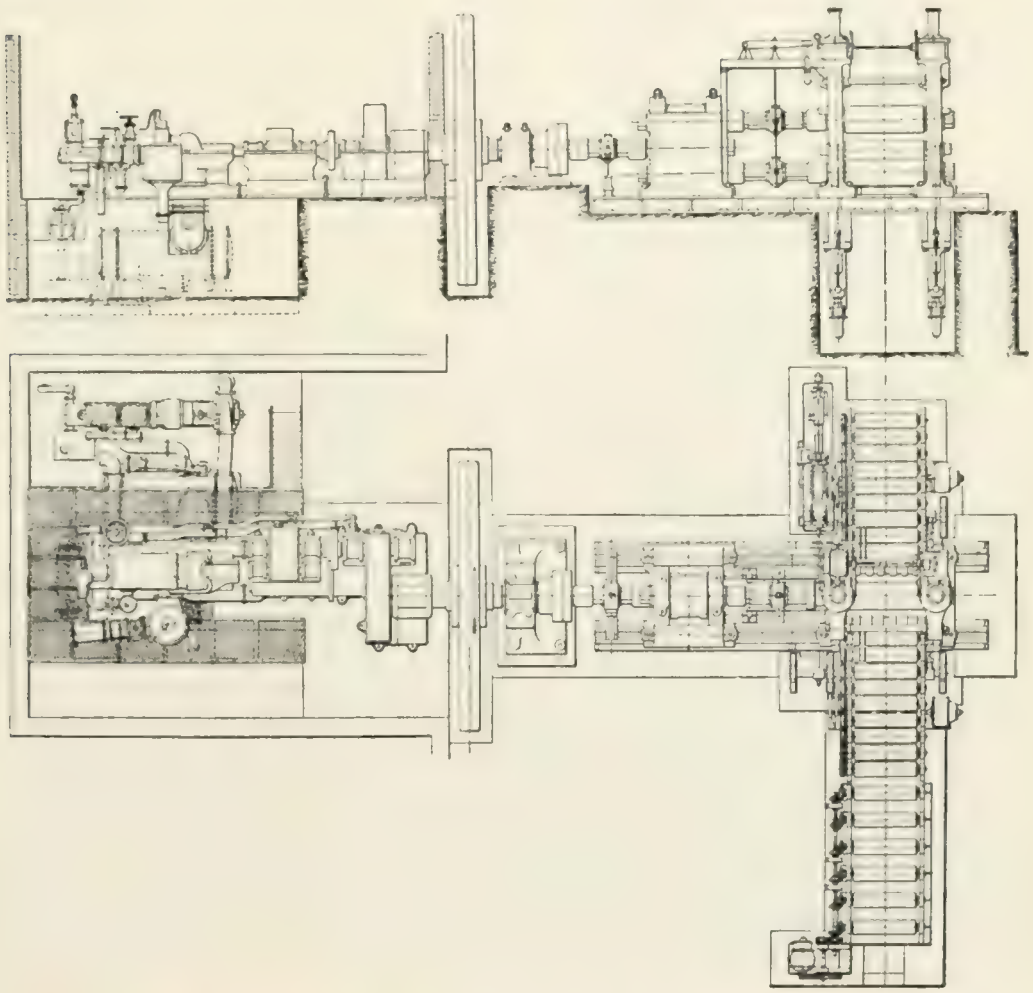


FIG. 25—TURBINE DRIVEN ROLLING MILL INSTALLATION
Calderbank Steel Work, Scotland.

The effect of the increased efficiency of both turbine and propeller in a marine installation has even a more far-reaching effect, as a large reduction in coal bunker capacity is also brought about, and, moreover, the boiler horse-power required is reduced approximately one-third. The saving of one-third of the space occupied by these boilers will be seen to be a very large item. As each of these ships carry 192 firemen and 123 trimmers, the reduction of the number of boilers to be fired, would effect a material reduction

in the expense for this part of the crew. There is another consideration which deserves mention, viz., if the increased space made available by the reduction in boiler and engine room and bunkers could not be profitably used, the general proportions of the vessel might be decreased, which would immediately have an accumulative effect and again reduce the amount of power required for propulsion.

The requirements for war ships are very different from those of fast passenger vessels which run normally at full speed, as war ships run at full speed only in case of emergency. When cruising, they use less than one-fourth of full power. As the efficiency of the existing marine turbine falls off rapidly at reduced (rotative) speeds, the steam consumption per horse-power-hour becomes serious when the ship is running at cruising speed. The desideratum is, therefore, a turbine capable of performing economically at both cruising and full-speed.

The Government is now conducting extensive trials of this method of propulsion and the result will be publicly reported in the near future. Plans have been made for the substitution of the turbines of the battleship North Dakota by smaller geared turbines and the improvement which will be effected will be of the nature already denoted.

The reduction gear now brings the lake steamers and slow going vessels within the domain of turbine application, and it is not unreasonable to presage that marine engineering will be revolutionized in the immediate future in a manner similar to that wrought by the turbine in stationary practice. There is besides the mechanical application, an hydraulic and electric system which have been tried out in marine work, but these are inherently inferior in both operation and efficiency. The hydraulic or Fottinger gear has been tested in Germany and within the last few months the U. S. Government has contracted for electrical equipment in order that comparative trials may be conducted and comparisions drawn with the geared outfit.

Rolling Mill Service—With the turbine now being used in the rolling mill by mechanical coupling to the rolls through gears, it has successfully encroached upon every important field of application of the reciprocating engine, with the exception of the reversing, hoisting and rolling mill service. While the reversing marine turbine is now an actuality, yet it is a problem whether the turbine will become a factor in stationary reversing work, especially in

small sizes. As the matter is of direct interest in connection with the development of the large power reduction gear, the essential facts of the geared turbine rolling mill installation of the Calderbank Steel Works, Scotland, are reproduced, together with a plan of the layout. Fig. 25 shows the general arrangement of the installation in elevation and plan. These were discussed at length in a paper read before the West of Scotland Iron and Steel Institute by Mr. A. Quinton Carnegie, extracts of which follow:

"The steam turbine is of the Parsons mixed-pressure type and is designed to run at 2000 revolutions per minute. * * * The mill runs at a speed of 70 r.p.m. and the speed of the turbine is reduced from 2000 r.p.m. in two steps, the intermediate shaft running at about 375 r.p.m. Both pairs of gears are arranged in cast-iron gear cases, which are provided with suitable white-metal-lined bearings for the shafts.

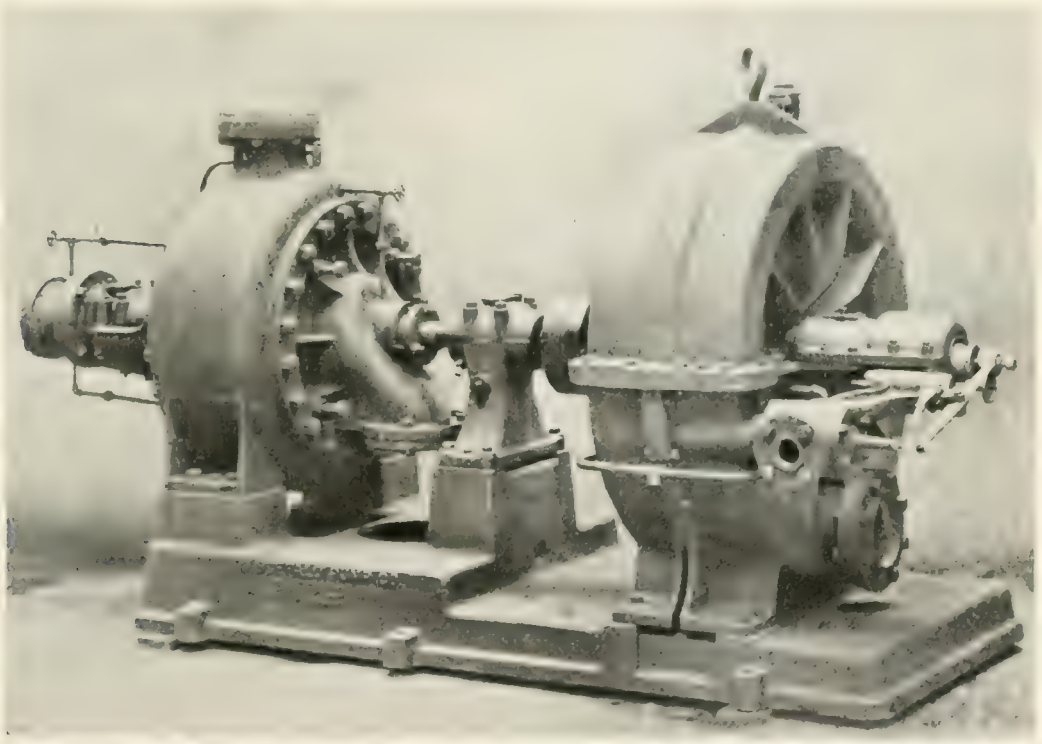


FIG. 24.—SINGLE STAGE TURBINE DRIVEN PUMP FOR LOW DUTY

* * * "Flexible couplings are fitted between the turbine and the high-speed pinion shaft, and also between the first and second reduction gears. The couplings allow for small errors in the alignment of the shafts, and also give the necessary end freedom for expansion of the steam turbine shaft.

* * * "The first slab was put through the mill on September 15, 1910, after the whole plant had been run slowly for several days, to allow the main bearings to settle down into working order.

* * * "Up to thirty slabs have been rolled in an hour, and the maximum size of the plate has been 60 feet long and about 6 feet wide, with a minimum thickness of 3/16 inch. The lifting tables for some time worked too slowly, but they have now been speeded up and take six seconds for the lift and fall.

* * * "The general experience which has been obtained with the working of this plant is sufficient to show that the experiment has proved a most gratifying success. The mill has been working regularly ever since the heavy

bearings have settled down into good working order and no trouble of any sort has occurred.

* * * "Referring now to the future fields which these two important experiments have opened up, the writer sees no difficulty in applying turbines to the driving of textile mills or other works which require large powers. The geared turbine will easily give the absolutely uniform speed of drive on which advocates of electric driving for cotton mills based all their claims, and it will give this without the intervention of electrical machinery with its power losses and heavy capital cost."

ADDITIONAL FIELDS OF APPLICATION

For the reasons which have made the turbine prominent in the applications previously mentioned, new fields have been constantly opening up for this interesting prime mover. Some of the more important ones are in connection with low duty pumps, air or gas compressors, train lighting sets, and locomotive headlighting outfits.

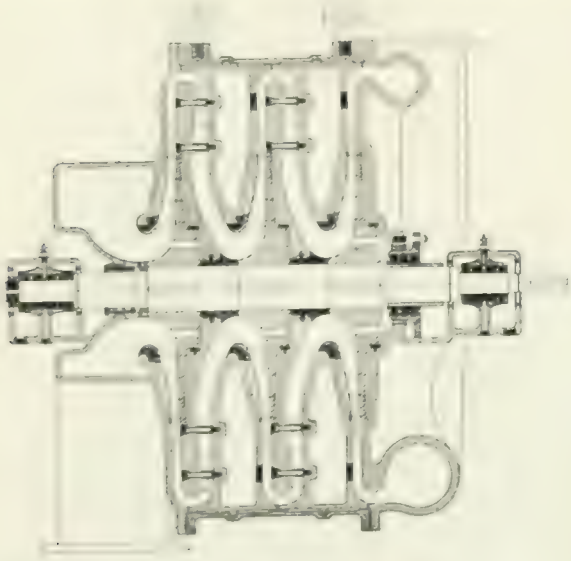


FIG. 27—THREE-STAGE CENTRIFUGAL AIR COMPRESSOR

For delivery pressures of 15 to 30 lbs. gauge.

Temporary work or cheap fuel may demand a pumping unit of low duty only. This would be satisfied by a single-stage pump direct coupled to a single turbine, as illustrated in Fig. 26.

Air and Gas Compression—One of the latest invasions of the stronghold of the reciprocating unit has been the building of high-pressure centrifugal compressors. In the past, neither the centrifugal pump nor compressor have been considered as being practical for high head work or pressure, owing to the poor showing made by the early types. The fundamental theory of centrifugal design has not heretofore been sufficiently understood and appreciated so that we are just awakened to the unusual possibilities of centrifugal units for this service.

Analysis of preceding constructions will show the entire lack of regard of the necessity of converting the kinetic energy represented by the final velocity into potential energy, so that 50 percent of the energy was lost merely in this way without reckoning the other losses attending its operation. There are several methods of

effecting this conversion, i. e., diffusion valves, volutes of proper design, and diffusion tubes or inverted nozzles, and the application of these is governed by the nature and extent of operation. Hence with proper designs, efficiencies of 60 to 85 percent are obtainable. Details of a high efficiency compressor designed for moderate pressures of 15 to 30 lbs. gage are given in Fig. 27. Several single impellers (as shown) may be placed on a common shaft and operated in series, each imparting an equal amount of energy to the air, and thus serially building up the pressure. Each succeeding impeller raises the pressure a higher degree than in the preceding stage, as may be quickly grasped in dividing up the compression card into equal divisions of work. Or, in other words, since the energy expended in each stage is the same, the pressure difference must be greater in

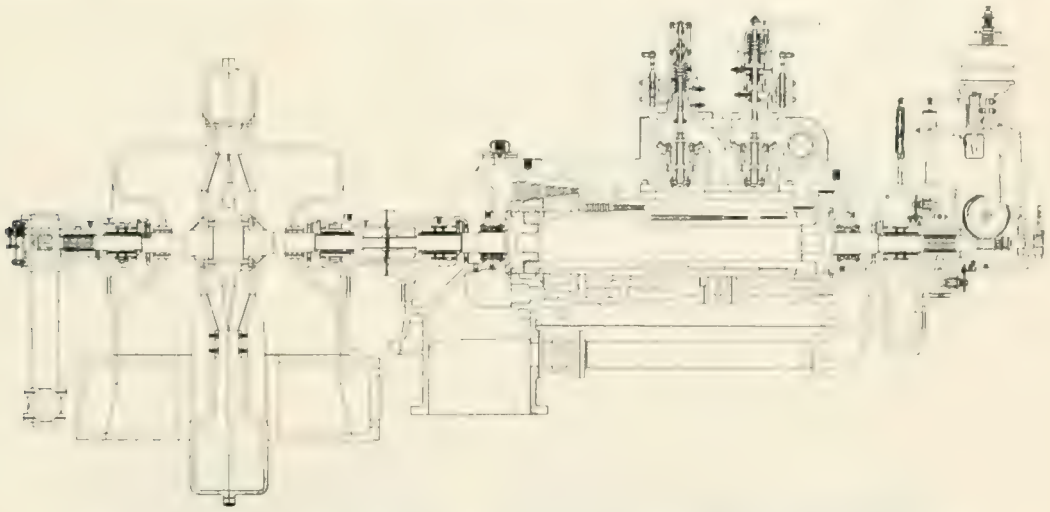


FIG. 28—LOW PRESSURE SINGLE-STAGE CENTRIFUGAL COMPRESSOR
For delivery pressures of two to four pounds.

as much as the volume delivered to the following impeller is less owing to its higher pressure. This follows from the formula, $PV^n = K$.

The noteworthy features of the multi-stage compressor is that the efficiency of the series of impellers is the average of each independent wheel; losses are not cumulative, as may be supposed. Blowers of this type may be conveniently built in sizes impractical in the reciprocating design. Freedom from pulsations and vibration in the system is a large factor in their favor, and foundation requirements also may be found to be a consideration. The other advantages of reduced attention and lubrication costs are evident with centrifugal construction.

Compressors of this type containing 10 or more stages are readily built for pressures of 80 to 100 lbs. It so happens that the centrifu-

gal compressor in Fig. 28 has been connected to a 700 horse-power reaction turbine of 3 600 r.p.m., and is correspondingly represented in sectional detail. This is probably one of the most familiar of turbine sections to engineers in general, and there is warrant in remarking that for this capacity and speed the design has proven

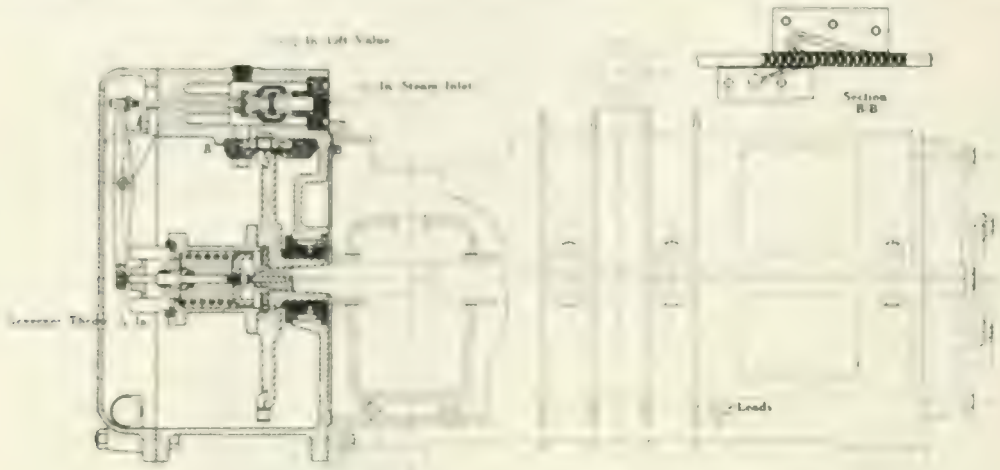


FIG. 29—SECTION THROUGH LOCOMOTIVE HEADLIGHTING SET

itself most efficient mechanically and thermodynamically.

Locomotive Headlight Sets—There are certain railway systems, especially single-track lines, which require special safety measures in order to operate fast trains and maintain schedules. A most

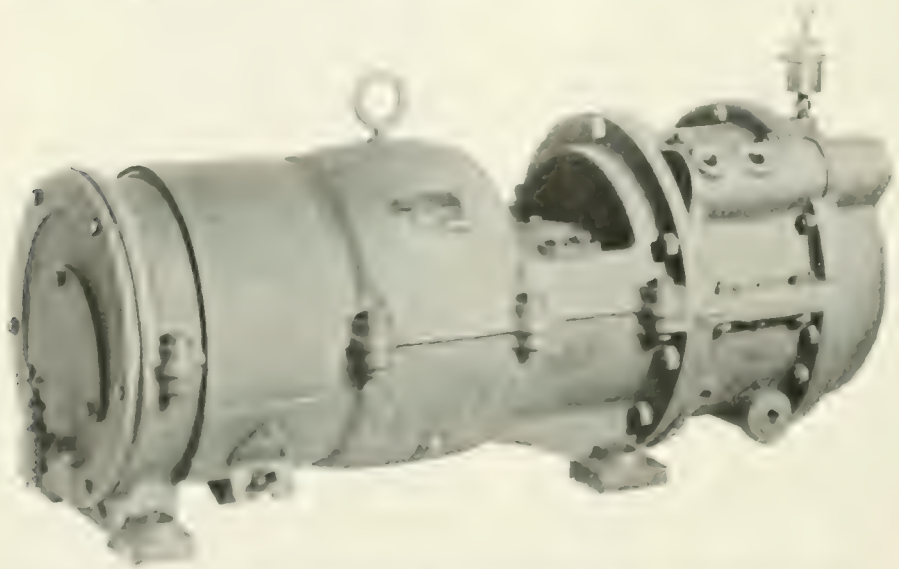


FIG. 30—TURBINE LOCOMOTIVE HEADLIGHTING SET

interesting application of the turbine responds to this need in supplying an electric arc headlight from a small self-contained generating set, mounted on the engine, either above the boiler or on the pilot. This penetrating light may be distinctly observed, in a line of unobstructed vision for a distance of over one mile

at night, and the radius of the engineer's sight extended 3 000 feet. Warning of danger ahead is therefore given in time to escape or avert accidents. It is no doubt understood by many that a number of states have enacted laws compelling trains to be equipped with electric headlighting sets, or other high candle power lamps, and the greater safety along these highways is evident. Reliability is therefore most important, and the simplest and most dependable mechanisms are demanded. Fig. 29 illustrates how some of the designs previously described have been reduced to such a satisfactory state. All parts of the turbine and generator are totally enclosed as shown in Fig. 30 and, therefore, weather-proof. The unit is but three feet in length and develops one kilowatt at 4 000 r.p.m., using about 185 pounds of steam per hour.

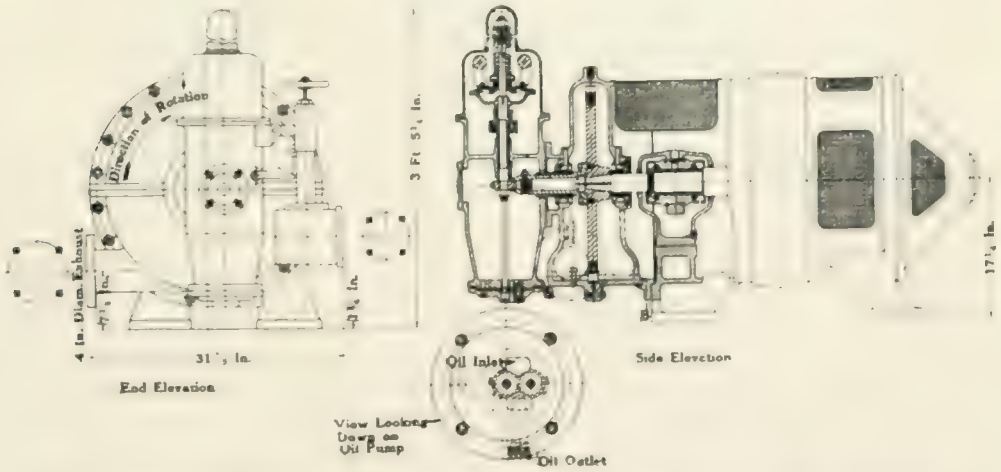


FIG. 31.—TURBINE DRIVEN GENERATOR FOR TRAIN LIGHTING SERVICE

Train Lighting Generating equipments driven from the axle of the car wheel, have been used for this service, and possess some advantages, but are plainly very complicated and undoubtedly require a high degree of supervision to maintain them at reasonable cost. They are possibly best suited to trains making short local runs, and in cases where the make up of the train is subject to frequent change, to avoid making and breaking electrical connection between successive cars. The storage battery outfit is the simplest installation, but the chief objection to this type is to be found in the attention required and the provisions for charging necessary at the terminals.

Steam-driven generating sets are the next in simplicity and probably form the most practical solution of the car lighting problem. Reciprocating steam engines have been used to some extent, and while their economy in units of small size is somewhat

superior to that of the turbine, the latter is to be preferred owing to its quiet operation. Units for such service, are generally installed in the baggage car, and in the absence of heavy foundations, the reciprocations of the engine may be felt throughout the entire

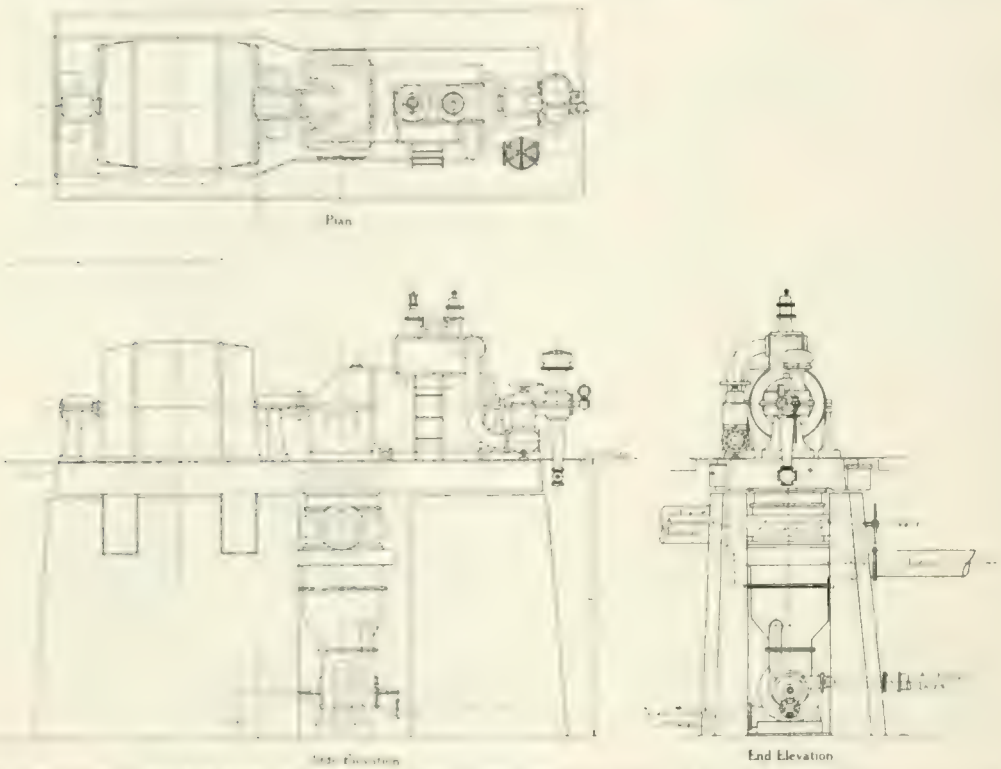


FIG. 32—ARRANGEMENT OF 1 000 KW TURBINE WITH LEBLANC CONDENSER AND AUXILIARIES DIRECTLY BENEATH BEDPLATE

train and have proved very annoying. The turbine, on the other hand, is inherently quiet-running and, moreover, its small floor space requirements possess a real value in this particular service.

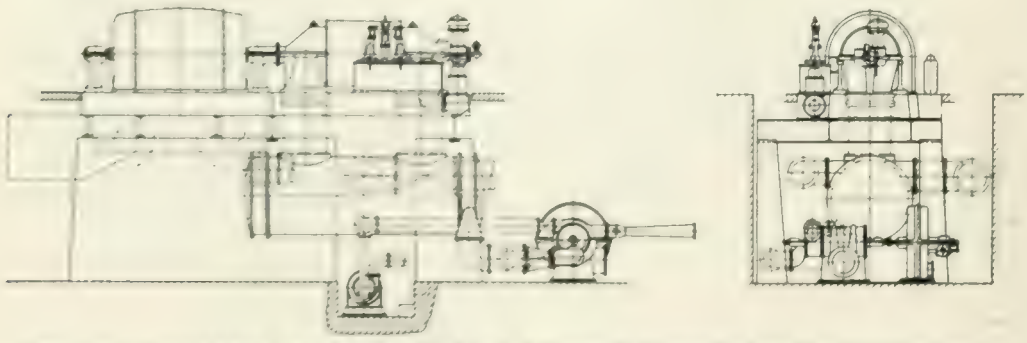


FIG. 33—COMPACT ARRANGEMENT OF SURFACE CONDENSER AND TURBINE-DRIVEN AIR, CIRCULATING AND HOT WELL PUMPS

A turbine driven equipment such as shown in Fig. 31 would obviously prove best for long distance "through" trains, all coaches being on one electrical circuit supplied from the single source.

The greatest advantage of the independent steam unit evidently

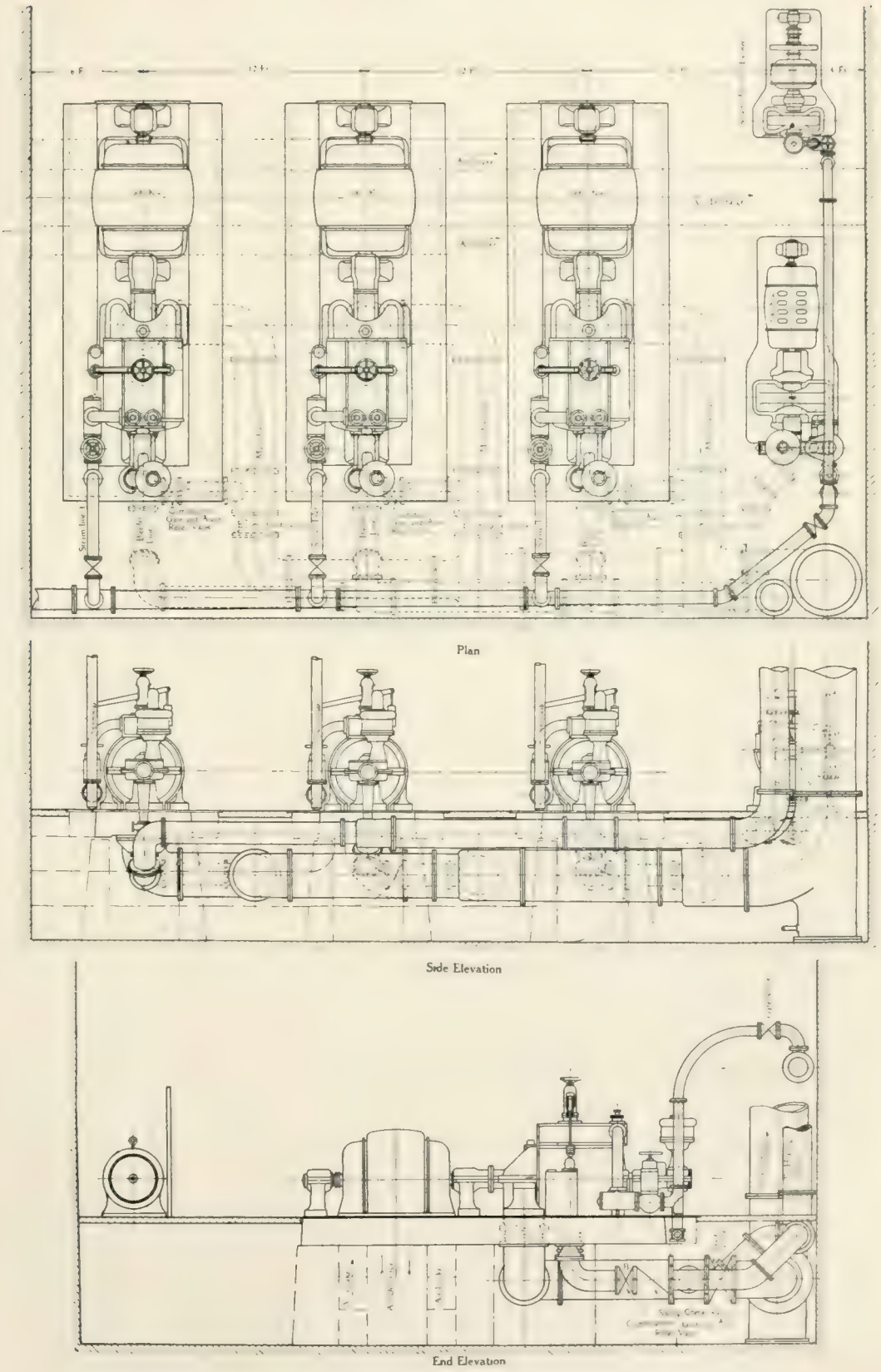


FIG. 34—LAYOUT OF AUTOMATIC BLEEDER TURBINES
For central station serving electrical and heating load.

lies in the possibility of maintaining continuous operation for any period, regardless of whether the train is in motion or at rest. This characteristic will be appreciated by those who have experienced prolonged delays in darkened cars.

SOME NEW TYPES OF INSTALLATIONS

For straight condensing operation, Figs. 32 and 33 show economical layouts as regards piping connections and compact arrangement of condenser and auxiliaries directly beneath the turbine, which obviously avoids obstructing the path of travel in the basement. Fig. 32 is of particular interest as it shows how simply and effectively turbine driven air and circulating pumps may be applied to surface condenser work and the minimum floor space requirements. Fig. 34 represents a typical layout of a central station equipped with automatic bleeder turbines serving a combined heating and electrical load. As to be noted, the arrangement of piping is exceedingly simple, the exhaust and bleeding connection from each unit delivering into common headers which lead respectively to a central condenser and the heating system. In some installations it may be the desire to divert all the steam from the turbine into the heating system. If the turbine is fairly well loaded, as it probably would be under these circumstances, it would prove more economical to have the steam pass through the entire turbine, providing none escapes to atmosphere. This could easily be accomplished by introducing gate valves *B* and *E*, Fig. 34, in the main exhaust and bleeder lines from each turbine and the inter-connection *C*. Then to run the low-pressure stages non-condensing, passing all steam to the heater system, valves *B* and *E* would be closed and the valve in connection *C* opened. With automatic bleeding operation, as normally obtains, *B* and *E* are open and *C* closed. Operating strictly condensing, *B* and *C* are closed, *E* obviously being wide open and the automatic valve on the turbine raised out of action.

CONCLUSION

In attempting to outline the numerous developments which have taken place in the turbine art in the past few years, one is compelled to omit many features which are of great interest, in order to avoid a discussion of greater length than at present is desired. It is hoped, however, that the facts which have been herein set forth will lead to a further study of these significant subjects.

STANDARDIZATION IN MANUFACTURING

AN INDUSTRIAL EXAMPLE

H. F. CHADWICK

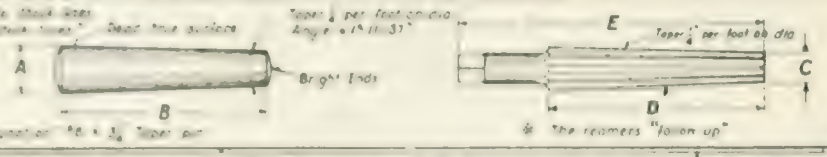
Standardization in its application to engineering products in general was discussed in the article by the author in the April issue. It was pointed out that standardization serves as a means of securing ease, economy and expedition of production, and that, provided it is not effected too soon or adhered to too tenaciously, the advantages in manufacturing decidedly overbalance the disadvantages. This is especially true in relation to the problem of carrying stock, which directly influences the delivery of apparatus. It is apparent that the larger a manufacturing company becomes, especially if it has a diversified product, the more necessary is standardization for economic and speedy production. This fact has been recognized by the managements of many large manufacturing companies. Some of the standard methods which have been evolved in a practical way by the Westinghouse Electric & Mfg. Company, with which the writer is connected, will be discussed in this article.

THE importance of standards for a large manufacturing company cannot be overestimated. Standardization work has been carried on for many years by the Electric Company. The early standardization work was carried on by the drafting department, on account of the absolute necessity for having standards for screws, bolts, rivets, wires and other similar parts which are being constantly specified by draftsmen. When the engineering department was rearranged eight years ago, the standard section was made a part of the engineering department. Since that time the scope of the work has been very much broadened, and the work has been prosecuted along many lines which were not attempted before.

There are few parts, methods, processes, or materials used in engineering work which do not make good subjects for standardization. In many cases standardization and systematization are synonymous, and it is generally the case that systematic men are most willing to adopt standards for their work.

Generally it is not difficult to convince an individual or a firm that standards are desirable; the difficulty comes in having the standards actually used. In a large firm, where there are many engineers and draftsmen, with a tendency toward change of personnel, the problem of keeping each man posted in regard to standards which should be followed is not a small one. This is done by means of standard books and various card indexes.

TAPER PINS & REAMERS



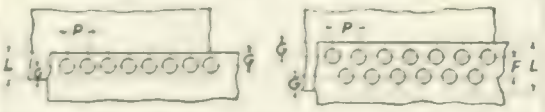
SIZE		PIN LENGTHS B																								REAMERS			
Diameter A / Approx. Decimal	No	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2	5 3/4	6	No.	Diameter C	Length D	Length E
1/16	0	•						•	•	•	•																		0	.135	1 1/2	2 1/4
5/64	1	•						•	•	•	•	•																	1	.146	1 3/4	2 1/2
3/32	2	•						•	•	•	•	•	•																2	.162	2	3
7/64	3	•						•	•	•	•	•	•	•	•	•													3	.183	2 1/4	3 1/2
1/4	4	•						•	•	•	•	•	•	•	•	•													4	.208	2 1/2	4
9/64	5	•						•	•	•	•	•	•	•	•	•													5	.240	3	4 1/2
5/32	6	•						•	•	•	•	•	•	•	•	•	•	•	•	•									6	.279	3 5/8	5
11/64	7							•	•	•	•	•	•	•	•	•	•	•	•	•									7	.331	4 1/2	6
1/8	8								•	•	•	•	•	•	•	•	•	•	•	•	•	•							8	.398	5 1/4	6 3/4
9/64	9									•	•	•	•	•	•	•	•	•	•	•	•	•	•	•					9	.482	6 1/8	8
13/64	10									•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	10	.581	7	9
																													11	.706	8 1/4	11 1/4
																													12	.842	10	13 3/8
																													13	1.009	12	16

Lengths marked thus ● are manufacturers' standard stock sizes.
The Diameter is taken measured at the large end. The small end diameter varies with the length.
Each reamer will average in commercial measure the next smaller size. In the shop this is called "following up." Discovering requires the diameter at a reamer to allow for this. It will be noticed that the total length is in every case considerably greater than the maximum lengths kept in stock by manufacturers.
Nos. 11, 12 and 13 are not kept in stock by manufacturers, and have to be made to order.

FIG. 1.

TANK DETAILS - FOR RIVETED TANKS

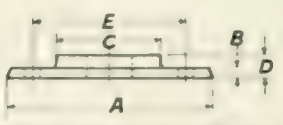
RIVETING



Thickness of Plate	SINGLE RIVETED JOINT					DOUBLE RIVETED JOINT					
	Dia of Rivet	Dia of Rivet Hole	Pitch P	Distance from centre of rivet to edge G	Lap L	Dia of Rivet	Dia of Rivet Hole	Pitch P	Distance between centres of rows F	Distance from centre of rivet to edge G	Lap L
3/16	1/2	9/16	1 1/4	7/8	1 3/4	1/2	9/16	2	1 1/4	7/8	3 1/16
1/4	5/8	11/16	1 3/4	1	2	5/8	11/16	2 1/4	1 1/2	1	3 1/2
5/16	3/4	13/16	2	1 1/8	2 1/2	3/4	13/16	2 1/2	1 3/4	1 1/4	4 1/4
3/8	7/8	15/16	2 1/4	1 1/4	2 7/8	7/8	15/16	2 3/4	2	1 3/8	4 7/8
7/16	1	1 1/16	2 1/2	1 3/8	3 1/4	1	1 1/16	3	2 1/4	1 5/8	5 1/2

This riveting is to be used on all joints and also on flanges at top of tank.

PIPE FLANGES



Size of Pipe	A	B	C	D	E	NUMBER OF RIVETS 1/2" or 5/8"	11/16" or 3/4"	7/8"	1"
3/4	6	5/16	1 7/8	1	4	6			
1	6	5/16	2	1	4	6			
1 1/4	6 1/2	5/16	2 1/8	1	4 1/2	8			
1 1/2	7	3/8	2 5/8	1 1/4	5	8			
2	8	3/8	3 1/8	1 1/4	5 1/2	8	8		
2 1/2	8 1/2	3/8	3 5/8	1 1/2	6	10	10		
3	9	3/8	4 1/4	1 1/2	6 1/2	10	10		
3 1/2	9 1/2	7/16	4 7/8	1 1/2	7	12	12		
4	10	7/16	5 1/8	1 1/2	7 1/2	12	12		
4 1/2	10 1/2	1/2	5 1/4	1 1/2	8	14	12		
5	11	1/2	6 1/2	2	8 1/4	14	12	12	
6	12 1/2	1/2	7 1/8	2	9 1/2	16	16	14	
7	14	5/8	8 1/4	2	10 1/4	18	18	16	14
8	15	5/8	9 1/4	2	11 1/4	20	18	18	16
9	16	3/4	10 7/8	2 1/2	12 1/4	22	20	20	18
10	17 1/2	3/4	12 1/4	2 1/2	14 1/4	24	24	22	20
12	20	3/4	14 1/2	2 1/2	16 1/4	30	28	26	22

No flange is to be used for oil gauge on 1/4" and thicker plate.

FIG. 2.

OFFICIAL STANDARD BOOK

The Electric Company's official standard book is a book of prints of about 350 pages, with the following general divisions:— Drawing System, Nomenclature, Fasteners, Wires and Cables, General Design and Figuring Data.

The sections on *Drawing System* and *Nomenclature* contain the sheets which might strictly be called a drawing dictionary, with sheets on lettering, dimensioning, finishes, gauging of material, sizes of drawings and example drawings. There are, in addition to these, an illustrated index showing the official names and characteristics of much used parts, and standard abbreviations.

In a modern drafting room, a draftsman should not be called upon to take the time to hunt for dimensions of standard parts. As soon as possible after a piece becomes standard every draftsman should have information in regard to its dimensions, so that whenever he wishes to use it he can promptly draw it to scale without having to hunt up the required information. For this reason there are many sheets on standard fasteners, such as bolts, screws, nuts, washers, keys, cotter pins, taper pins, rivets, etc., also complete data in regard to straps, wires and cables, which form a very important part of all electrical apparatus. (See Fig. 1)

Under *General Design* are many valuable sheets which are intended to produce uniformity, not only among machines or parts of machines of one particular line, but all lines of machines. The more of these standards that are available, the more uniform, obviously, will the product become. (See Figs. 2, 3 and 4)

The section on *Figuring Data* is composed, in part, of information collected from reliable outside sources, which is recognized and used more or less generally all over the country, and is arranged in convenient form for reference by engineers and draftsmen. The balance of the sheets in this section represent formulas and data which are entirely original or original in application with the Electric Company. (See Figs. 5 and 6)

PART INDEX

Over nine years ago a scheme was devised for keeping a record of parts that are likely to be duplicated. This scheme as now in effect consists of what may be called a card picture index of parts, one box from which is shown in Fig. 7. The part to be indexed is

METHOD OF WINDING COILS FOR OPEN SLOT MACHINES

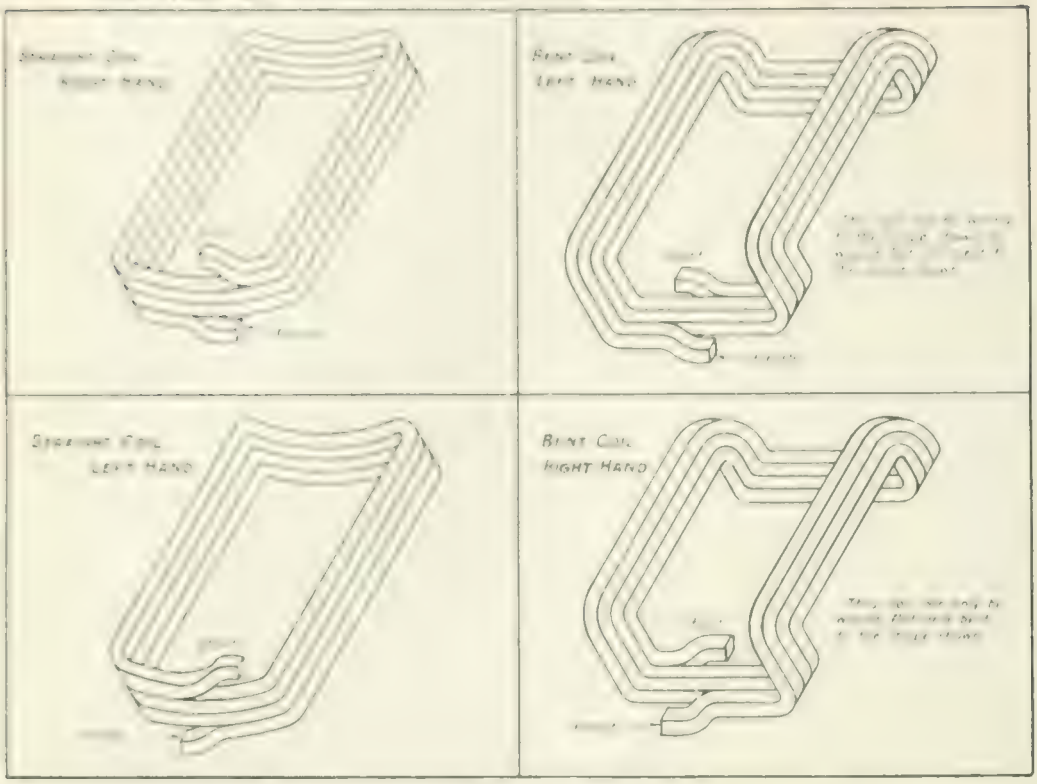
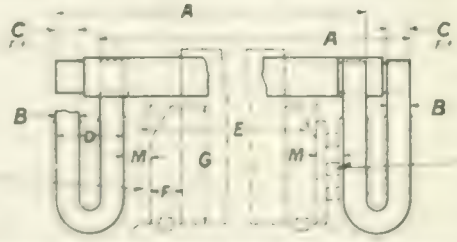


FIG. 3.

MANUFACTURING ALLOWANCES - WINDINGS

INDUCTION MOTORS
ROTOR AND STATOR WINDINGS - MINIMUM ALLOWANCES IN DIRECTION OF SHAFT



* Sketch shows all bars of equal length. A In some windings the bars are of unequal length. In either case the value H should be added to the total length of each bar. Sketch shows condition where there is contact of insulating material between end connector and end plate.

Sketch shows condition where free air space exists between end connector and end plate.

H = Variation in value of H for bars and fixing on face of C		J = Variation of D in bending		K = Variation of E for Face of End Plates		ALLOWANCE FOR INSULATION
Strap B	ADD TO A & H	Strap B	ADD TO A J	Bars G / F	ADD TO A K	L
1" and less	1/16	1" and less	1/16	1	1/64	Insulation clearance space, covering all variations in insulation will be shown on end sketches from which Engineers will check M on drawings
				2	1/32	
				3	3/64	
				4	1/16	
Above 1"	1/8	Above 1"	1/8	5	5/64	
				6	3/32	
				7	7/64	
				8	1/8	

INSTRUCTIONS TO DRAFTSMEN. M = Total clearance between bare End Connector and End Plate, should be shown on Drawing = 1/16 + 1/8 + L. M with these variations will then leave length L between bare copper of End Connector and End Plate.

FIG. 4.

sketched with its proper dimensions, the sketch being sufficiently clear to identify the part by the picture. The sketch is placed on the guide card in the index, and after being photographed down to small dimensions, also appears on the ear of the card. The information cards, giving sufficient detail for any ordinary identification of a drawing, follow the guide card. The classification is by subjects, and then by shapes. At the present time about 700 subjects are indexed, and these are being added to from time to time. This has required the making of between 2 100 and 2 200 sketches, and the master index contains something over 50 000 information cards, each infor-

WEIGHTS OF MATERIALS - METAL SHEETS

SHEET - WEIGHT PER SQUARE FOOT													
GAUGE SIZE	Commercial Spring	Commercial	Commercial	Commercial	Commercial	GAUGE SIZE	Commercial Polished Sheet Iron Gauge Number 20	Commercial Polished Sheet Iron Gauge Number 16	GAUGE SIZE	Spring	GAUGE SIZE	Commercial
	COPPER Sp. Gr. 8.618	BRASS Sp. Gr. 8.218	GER SIL Sp. Gr. 8.6	ALUMINUM Sp. Gr. 2.604	PLATINUM Sp. Gr. 21.5		STEEL Sp. Gr. 7.854	W I Sp. Gr. 7.688		STEEL Sp. Gr. 7.854		ZINC Sp. Gr. 7.19
4/0	20.84	19.69	20.59	6.38	51.44	5/0	0.40	0.0	454	8.52	5/0	8.10
4/0	18.55	17.53	18.34	5.68	45.8	469	9.25	18.15	425	7.94	4/0	7.3
365	16.52	15.61	16.31	5.07	40.8	438	8.65	16.95	380	7.1	3/0	6.75
325	14.72	13.92	14.54	4.51	36.35	406	8.05	15.75	340	6.41	2/0	6.08
289	13.12	12.38	12.95	4.01	32.35	375	7.45	14.6	300	5.64	0/0	5.34
258	11.67	11.03	11.53	3.57	28.8	344	6.85	13.4	284	5.31	1/0	5.07
229	10.39	9.82	10.27	3.18	25.65	312	6.25	12.25	259	4.84	2/0	4.81
204	9.25	8.74	9.14	2.83	22.85	281	5.65	11.05	238	4.45	3/0	4.61
182	8.24	7.79	8.15	2.52	20.35	266	5.3125	10.425	220	4.18	060	4.25
162	7.34	6.93	7.25	2.25	18.1	250	5.0	9.80	203	3.86	055	4.15
144	6.54	6.18	6.47	2.0	16.1	234	4.6875	9.175	180	3.4	050	4.0
128	5.82	5.50	5.76	1.78	14.35	219	4.375	8.55	165	3.13	045	3.88
114	5.18	4.90	5.13	1.59	12.81	203	4.0625	7.925	148	2.8	040	3.70
102	4.62	4.36	4.56	1.41	11.4	188	3.75	7.3	134	2.57	035	3.53
091	4.1	3.88	4.06	1.26	10.15	172	3.4375	6.675	120	2.30	031	3.37
0818	3.66	3.46	3.61	1.12	9.05	156	3.125	6.050	109	2.15	028	3.21
0720	3.26	3.08	3.23	1.018	8.1	141	2.8125	5.425	95	1.88	024	898
0641	2.90	2.74	2.87	.899	7.1	125	2.50	4.800	083	1.59	022	748
0571	2.59	2.44	2.56	.794	6.28	109	2.1875	4.1875	072	1.34	020	673
0508	2.30	2.18	2.28	.708	5.64	0938	1.875	3.550	065	1.16	018	598
0453	2.05	1.92	2.03	.630	5.02	078	1.5625	2.925	058	1.01	016	524
0403	1.83	1.71	1.81	.561	4.47	0703	1.4063	2.612	049	2.00	012	449
0359	1.63	1.54	1.61	.498	4.0	0625	1.25	2.300	042	.71	010	374
0320	1.45	1.37	1.43	.445	3.57	0561	1.1250	2.175	035	.43	008	299
0285	1.29	1.22	1.28	.397	3.19	0500	1.04	2.050	032	.31	006	224
0254	1.15	1.08	1.13	.352	2.83	0438	1.005	1.950	028	.24		
0226	1.02	0.96	1.01	.31	2.52	0375	.53	1.800	025	.22		
0201	.91	0.86	0.89	.278	2.25	0344	.4025	1.375	022	898		
0179	.81	0.76	0.80	.248	2.0	0313	.215	1.550	020	8.15		
0159	.72	0.68	0.71	.220	1.78	0281	.4125	1.525	018	7.45		
0142	.643	0.604	0.631	.196	1.59	0250	1.00	1.000	016	6.65		
0126	.573	0.541	0.561	.175	1.41	0219	0.8025	0.875	014	5.7		
0113	.510	0.480	0.500	.156	1.26	0188	0.765	0.750	013	5.30		
0100	.454	0.428	0.445	.139	1.11	0172	0.725	0.687	012	5.0		
0089	.404	0.381	0.396	.124	0.994	0.0156	0.675	0.625	010	4.08		
0080	.361	0.339	0.353	.110	0.887	0141	0.6375	0.575	009	3.8		
0071	.321	0.303	0.314	.098	0.788	0125	0.5625	0.500	008	3.5		
0063	.286	0.270	0.282	.088	0.705	0.0219	0.446	0.437	007	2.91		
0056	.254	0.240	0.251	.078	0.629	0.0172	0.414	0.406	005	2.15		
0050	.226	0.214	0.224	.070	0.561	0.0140	0.362	0.375	004	1.63		
0045	.202	0.190	0.199	.062	0.499	0.0109	0.35	0.344				
0040	.180	0.170	0.178	.055	0.445	0.0078	0.9	0.3				
0035	.162	0.153	0.160	.050	0.395	0.0047	0.287	0.28				
0031	.142	0.135	0.141	.044	0.350	0.0016	0.27	0.266				
							0.255	0.25				

FIG. 5.

mation card containing on an average of four items, making a total of over 200 000 items which have been indexed.

This index was started in an experimental way with a few subjects. Later it was decided to make it the medium for locating parts of apparatus. In the making of the index it was therefore necessary to go back over old drawings, and in doing this approximately 120 000 drawings had to be examined, and the items taken off and classified. This work when done, however, was of very lasting value, for the reason that for any subject indexed it should be possible in a few seconds time to find any drawing which has been

made for the particular part in question. As the items are indexed on the information cards by the principal or more important dimensions, as for example, the diameter of bearings, the search for a particular item may soon be narrowed down to a very few drawings.

SOLID CIRCULAR SECTIONS

Section Modulus = $\frac{\pi d^3}{32}$ — Moment of Inertia = $\frac{\pi d^4}{64}$

Shaft Dia.	$\frac{\pi d^3}{32}$	$\frac{\pi d^4}{64}$	Shaft Dia.	$\frac{\pi d^3}{32}$	$\frac{\pi d^4}{64}$	Shaft Dia.	$\frac{\pi d^3}{32}$	$\frac{\pi d^4}{64}$	Shaft Dia.	$\frac{\pi d^3}{32}$	$\frac{\pi d^4}{64}$	Shaft Dia.	$\frac{\pi d^3}{32}$	$\frac{\pi d^4}{64}$
1/8	[illegible]	[illegible]	2	7854	7854	5	12 27	30 68	8	50 27	201 1	11	130 7	718 7
1/4	[illegible]	[illegible]	2 1/16	[illegible]	1 031	5 1/16	13 40	33 89	8 1/16	52 66	213 9	11 1/16	135 2	751 9
3/8	[illegible]	[illegible]	2 1/8	1 118	1 258	5 1/8	14 11	37 30	8 1/8	55 13	227 4	11 1/8	139 8	786 3
7/16	[illegible]	[illegible]	2 3/16	1 315	1 502	5 3/16	15 26	40 97	8 3/16	57 67	241 5	11 3/16	144 5	821 8
1/2	0344	0155	2 1/4	1.534	1.917	5 1/4	16 [illegible]	44 92	8 1/4	60 29	256 2	11 1/4	149 3	858 5
9/16	[illegible]	[illegible]	2 5/16	1 776	[illegible]	5 5/16	17 47	49 14	8 5/16	62 99	271 6	11 5/16	154 2	896 5
5/8	[illegible]	[illegible]	2 3/8	[illegible]	[illegible]	5 3/8	18 66	53 66	8 3/8	65 77	287 7	11 3/8	159 3	935 7
11/16	[illegible]	[illegible]	2 7/16	[illegible]	[illegible]	5 5/16	19 91	58 48	8 5/16	68 63	304 5	11 5/16	164 4	976 1
3/4	[illegible]	0491	2 1/2	[illegible]	[illegible]	5 1/2	21 21	63 62	8 1/2	71 57	322 1	11 1/2	169 6	1017 9
13/16	1475	[illegible]	2 9/16	[illegible]	4 681	5 9/16	22 [illegible]	69 09	8 9/16	74 59	340 3	11 9/16	175 0	1061 0
7/8	[illegible]	[illegible]	2 5/8	3 370	5 477	5 5/8	24 [illegible]	74 93	8 5/8	77 59	359 4	11 5/8	180 5	1105 4
15/16	[illegible]	[illegible]	2 11/16	3 574	6 009	5 11/16	25 41	81 03	8 11/16	80 59	379 2	11 11/16	186 1	1151 2
1	[illegible]	[illegible]	2 3/4	3 789	7 366	5 3/4	[illegible]	87 62	8 3/4	84 17	399 8	11 3/4	191 7	1198 4
1 1/16	[illegible]	[illegible]	2 13/16	[illegible]	8 476	5 13/16	[illegible]	94 76	8 13/16	87 54	421 3	11 13/16	197 6	1247 1
1 1/8	[illegible]	[illegible]	2 7/8	[illegible]	[illegible]	5 7/8	[illegible]	[illegible]	8 7/8	90 99	443 6	11 7/8	203 5	1297 2
1 3/16	[illegible]	[illegible]	2 15/16	[illegible]	11 07	5 15/16	[illegible]	[illegible]	8 15/16	94 54	466 8	11 15/16	209 5	1348 8
1 1/4	[illegible]	[illegible]	3	[illegible]	[illegible]	6	[illegible]	117 9	9	98 17	490 9	12	215 7	1402 0
1 5/16	[illegible]	[illegible]	3 1/16	[illegible]	14 41	6 1/16	[illegible]	[illegible]	9 1/16	101 9	515 9	12 1/16	222 0	1456 7
1 3/8	[illegible]	[illegible]	3 1/8	[illegible]	[illegible]	6 1/8	41 41	135 6	9 1/8	105 7	541 8	12 1/8	228 4	1513 0
1 7/16	[illegible]	[illegible]	3 3/16	[illegible]	[illegible]	6 3/16	[illegible]	[illegible]	9 3/16	[illegible]	568 8	12 3/16	234 9	1570 9
1 1/2	[illegible]	[illegible]	3 1/4	[illegible]	[illegible]	6 1/4	41 42	144 [illegible]	9 1/4	113 9	596 7	12 1/4	241 5	1629 4
1 9/16	[illegible]	[illegible]	3 5/16	[illegible]	[illegible]	6 5/16	[illegible]	[illegible]	9 5/16	117 8	625 6	12 5/16	248 3	1691 7
1 5/8	[illegible]	[illegible]	3 3/8	[illegible]	[illegible]	6 3/8	45 79	177 1	9 3/8	122 0	655 5	12 3/8	255 2	1754 6
1 11/16	[illegible]	[illegible]	3 7/16	[illegible]	[illegible]	6 7/16	47 [illegible]	[illegible]	9 7/16	126 3	686 6	12 7/16	262 2	1819 3

It should be noted that the Section Modulus and the Moment of Inertia given are for bending only. The polar moment of inertia used in torsion formulas is, for circular sections, double the moment of inertia with respect to an axis lying in the section and passing through its center.

FIG. 6.
Section of page from Standard Book

The part index is not intended to take the place of working drawings, but is merely a means of *finding* the proper drawings for any given subject. When it was decided to complete the index, a very careful survey was made through the different engineering and drafting divisions to determine what parts should be indexed

and what should be omitted. The original list of parts decided upon as all that it would be necessary to index was about 350. This was followed by constant requests to index additional parts, until the number grew to its present value—about twice the number originally decided upon. On account of new designs being made continually, new shapes are constantly appearing for those parts which are already indexed.

An attempt is now being made to indicate in the index the parts which are standard, the parts preferred, and the obsolete designs, as a guide for those who use the index, to prevent as far as possible the duplication of parts which it is desirable to discon-

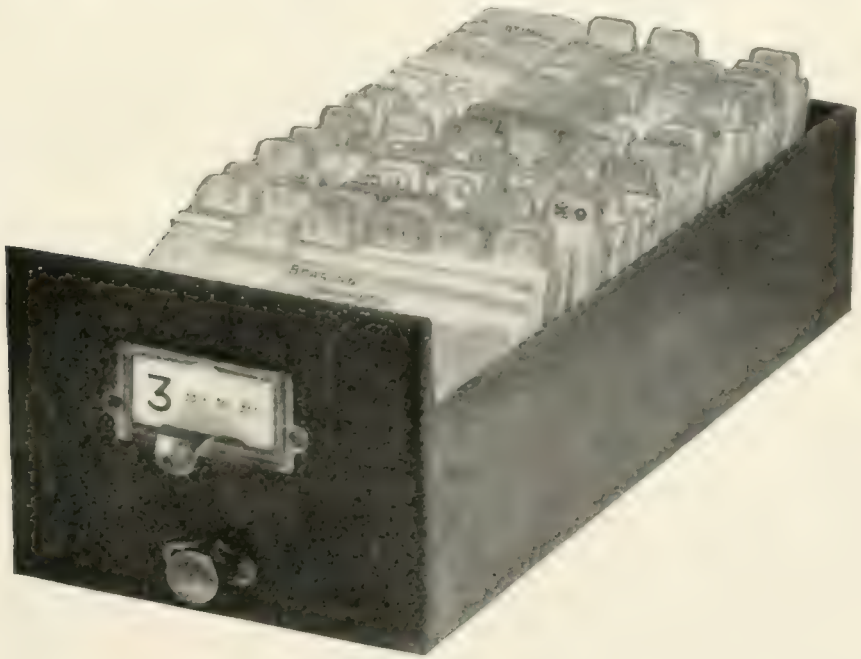


FIG. 7.

tinue. The value of such an index in connection with a modern drawing system should at once be apparent. Not only is a draftsman able to find any design which has been made and thereby avoid the making of new drawings, but he is able to follow the standard lines of design which have already been laid out.

Before the introduction of this index, it frequently occurred that in different lines of design (for example, alternating-current and direct-current motors) handled by different men, totally different methods were used in parts which might be identical. The part index creates a tendency for these designs to be merged together and for common parts to be used for many of the details.

(To be continued)

DETERMINATION OF FRICTIONAL RESISTANCE OF MINE CARS

G. W. HAMILTON

THE importance of having definite information, obtained from actual test, regarding the frictional resistance of mine cars, as a basis for determining the weight of locomotive and in turn the capacity of motor equipment required to meet given conditions of service in working up mine haulage propositions, was very forcibly brought out in a recent article on mine locomotives.* For many years the builders of electric locomotives assumed this resistance to be from 30 to 40 pounds per ton of 2 000 pounds, regardless of the size and weight of the car, or the kind of wheels and journals with which it had been equipped. These figures were fairly accurate ten years ago when mules were generally employed to secure the output, and the cars were made small and light in order that several per trip might be hauled by each mule, thus serving the greatest number of rooms and entries. With increase in the size of mines, involving larger outputs to be hauled from greater distances by electric locomotives, not only has the capacity of the mine car been increased, but its weight and strength has also been increased to meet the new conditions.

One can readily understand the significance of these changes in the method of haulage, and consequent changes in construction, when it is recalled that a mule is used to haul about four cars to a trip on an average, and that some locomotives today are hauling eighty. As the increased length of the trip (train) permits coal to be brought from an increasing distance without additional cost for labor, the tendency will be to use larger and heavier cars having less frictional resistance.

METHODS OF MEASURING

Several practical methods are available for obtaining the frictional resistance of the cars in use at a mine. Four of these are briefly outlined below.

Approximate Measurement by Observation—Ascertain the grade on which loaded cars are run down onto the cage in a shaft mine, to the end of the rope in a slope mine, or the grade of the return track on which the empty cars are run, at the tipple of a drift

*See article on "Determination of Weight and Equipment of Mine Locomotives" in the JOURNAL for Nov. 1911, p. 980, and editorial, p. 969

mine.* With this information at hand, watch the cars from the time the sprags have been withdrawn from the wheels, or the brakes released, in a shaft or slope mine, and note how they operate from this moment until on the cage or coupled to the rope. Do the cars have to be pushed to start them, or do they start themselves? Do the cars have to be gently pushed to the cage or the rope, or must they be held back and to what extent? In the case of the cars on the tipple, note how slowly or how fast they run along the empty track after leaving the dump.

Having watched a considerable number of cars in this service, an idea may be formed, within a few pounds, of the average frictional resistance, when it is known that the effect of each one per cent of grade is equivalent to a force of 20 pounds per ton of 2 000 pounds. In other words, if the grade is 1.5 percent (equivalent to 30 pounds per ton) and the cars, after being gently started, complete the trip, the resistance due to friction is a little less than the force exerted by the grade, or about 28 pounds. If, when the sprags are withdrawn, or the brakes released, the cars start themselves, the frictional resistance will range from 20 to 25 pounds per ton, a good deal depending on how fast each car runs in the distance available. On the other hand, if the cars have to be pushed to the cage or rope, the resistance must be more than the force exerted by the grade, and will run from 35 to 40 pounds per ton, or more, depending on the force required to push them.

There are several objections to this method of procuring the frictional resistance of the cars in mines entered by shaft or slope, one being that it is applicable to loaded cars only, whose resistance per ton is generally less than that of empty cars, while it is the resistance of the empty cars that is desired; another, that it cannot be applied successfully if the mine is idle.

By Measurement of Minimum Coasting Grade.—A method that may be followed in any mine in which the track has been laid and the cars purchased, is to obtain an empty car and push it along the entry or tipple until a stretch of straight track is found where it will just slowly coast a few yards after having been gently started. Then secure the grade on this stretch of track by using a straight edge and level, or long level such as is used by the mine carpenter, or by the method of using a tape, referred to above. After testing several cars, estimate the resistance of each by using 20 pounds per ton

*See "A Convenient Method of Determining Grades," in the JOURNAL for June, 1911, p. 569.

of 2 000 pounds for each percent of grade. For instance, if a five foot straight edge, placed along the top of one rail, has to be raised ¾ inch at one end to make it level, the grade is ¾ inch in five feet, or 15 inches in 100 feet, or 1¼ percent. The resistance of the cars, due to friction, therefore, is about 24 pounds per ton. It should be remembered that the weight of the car does not enter into the calculation, but simply the percentage of grade.

Using Dynamometer or Spring Balance—If a dynamometer or a small spring balance, with a capacity of about 100 pounds, is at hand, the resistance may be obtained by slowly and steadily pulling several empty cars, one at a time, against a grade of, say, one percent occurring on a stretch of straight track. It is best to haul the cars against a grade so that the resistance due to grade will require a constant pull and permit an accurate reading of the scale to be made. When the record has been taken, simply deduct from the total the resistance due to grade, and the remainder may be charged to friction.

Auxiliary Track Method—If the mine is idle, and a test cannot be made on the regular track, a close estimate of the resistance may be secured by laying a track, one rail in length, by spiking two rails on top of two long timbers which in turn are supported on several cross sills, the two end ones being about 15 feet apart. Then place an empty car on this improvised track, and having carefully leveled it, raise one end until the car will just slowly coast after being gently started. The grade required to accomplish this can then be measured and thus the frictional resistance determined. It is, of course, an advantage to secure the test of the mine cars under actual working conditions, but at times this cannot be done. The weight of the empty cars should also be obtained as correctly as possible, as well as a record of the loads in several cars; both figures are usually kept on file in the office or the scale house.

IMPORTANCE OF DEFINITE FIGURES

To further illustrate the value of this information, some examples are given to show the difference a few pounds of resistance per ton due to friction will make in the size and capacity of a locomotive, when the grades are against, and also in favor of the load, the figures being taken from mine records.

Weight of empty cars	2 400 pounds each
Weight of load in cars	8 000 pounds each
Case 1: Grade against the loads...	3 percent for 2 000 feet
Case 2: Grade with the loads.....	3 percent for 2 000 feet

The frictional resistance of the cars was not specified by the mining company which had ordered the locomotive, and it was, therefore, assumed to be 30 pounds per ton. The correct resistance was found to be 20 pounds per ton.

Case 1—At 20 pounds frictional resistance per ton, hauling 15 loads against the three percent grade with a 14 ton locomotive, requires a drawbar pull of 6 240 pounds and a tractive effort of 7 360 pounds. To take care of this load, at 250 volts, would call for 470 amperes. To haul the same load up the grade with a frictional resistance of 30 pounds per ton, the drawbar pull would be 7 020 pounds, and the tractive effort, with a 16 ton locomotive, 8 300 pounds. To take care of this load would require 520 amperes at 250 volts, or 50 amperes more than called for by the actual conditions, and enough to operate continuously a 32 horse-power motor.

Case 2—If the 14 ton locomotive was to be used to control a *maximum* trip of loaded cars down the three-percent grade, an estimate would place the number at 40, assuming the frictional resistance at 30 pounds per ton, but with the frictional resistance in reality 20 pounds per ton, the maximum load would be only 31 cars.

These figures prove that an error amounting to ten pounds per ton in the resistance, due to friction, calls for an increase of two tons in the weight of the locomotive, when the loads are to be hauled up grade, and reduces by nine cars or 46.8 tons, the weight of the maximum allowable trip which should be controlled coming down grade.

In the first case the mine owner would have been called upon to purchase a locomotive two tons heavier than required for his service, and in the second case an accident might occur if a load 46.8 tons above rating were handled down grade if, for instance, some obstruction were seen on the track demanding a stop.

That the frictional resistance of up-to-date heavy mine cars is an uncertain quantity is proven by records which have been obtained within the past few months, there being a variation of 23 pounds per ton, or from 17 to 40 pounds in tests made at twelve properties in the state of Pennsylvania. To those interested in mine work, these records should prove the importance of securing all details on the ground when electric haulage is planned, and will serve to show how the cost per ton for haulage may be kept down, or the output increased, if good cars and good track are maintained.

SINGLE-PHASE COMMUTATOR MOTORS

MOTORS WITH SHUNT-CONNECTED COMMUTATING POLES

R. E. HELLMUND and E. W. P. SMITH

IN the two previous articles on this subject commutation has been dealt with to some extent. In the first article, it was pointed out that commutation can be made satisfactory by keeping the magnetic flux per pole in the motor at a sufficiently low value. In the second article, it was shown that arcing at the commutator can be reduced by putting a "preventive" resistance lead in series with the short-circuited armature coils. As a third means for improving the commutation, the use of commutating poles for the purpose of inducing a voltage equal and opposite to the short-circuit voltage suggests itself. If such a voltage could be induced by commutating poles, it would mean that the resultant voltage in the armature coils which are under commutation would be zero, and this of course would be an effective means for preventing any sparking whatsoever. Before considering the possibilities of inducing such a voltage, it seems advisable to recapitulate briefly the commutation phenomena and to investigate the question of the magnitude and phase relation of the voltage to be induced by the commutating pole to give the desired results.

As previously pointed out, the fluctuating nature of the main field flux induces a voltage in the coils during commutation. Like any voltage induced by fluctuations of field flux (transformer action) this voltage lags 90 degrees vectorially behind the flux, and will have to be considered in this relation in all the diagrams here shown. It has also been pointed out that the armature currents set up a cross flux in the armature, and that if this cross flux is allowed to exist, an electromotive force will be induced in the coils under commutation on account of the fact that these coils cut the cross flux as they rotate. The greater part of this cross flux is eliminated in an alternating-current motor which is provided with an auxiliary winding. Since there is, however, a certain space between the armature coils and the auxiliary winding, it is possible for some lines of the cross flux, which may be termed the leakage flux, to find a path through this space, as indicated in Fig. 1. As will be seen from this figure, these fluxes pass partly across the armature slots from one tooth to the other. This part of the leakage is usually called the slot leakage. Other lines of force may pass from the top of one armature tooth to the pole

face, and back to the top of the next armature tooth. This part of the leakage flux is usually termed the "zig-zag" leakage flux. Other leakage lines of similar effect can form at the end connections of the armature coils outside of the iron core. All of these lines are interlinked with the armature coils only, and therefore they cannot be compensated for by the auxiliary winding, which has been assumed to be of the same strength as the armature winding. It should moreover be realized that all of these lines are stationary in space, due to the fact that the space distribution of current in the armature does not change with the rotation of the

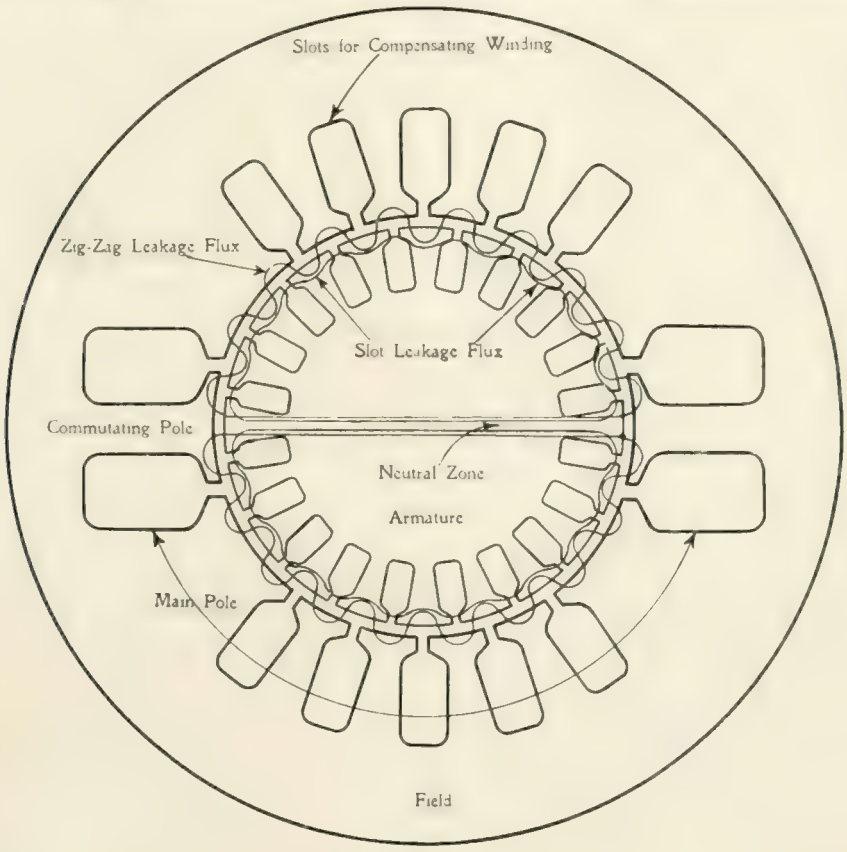
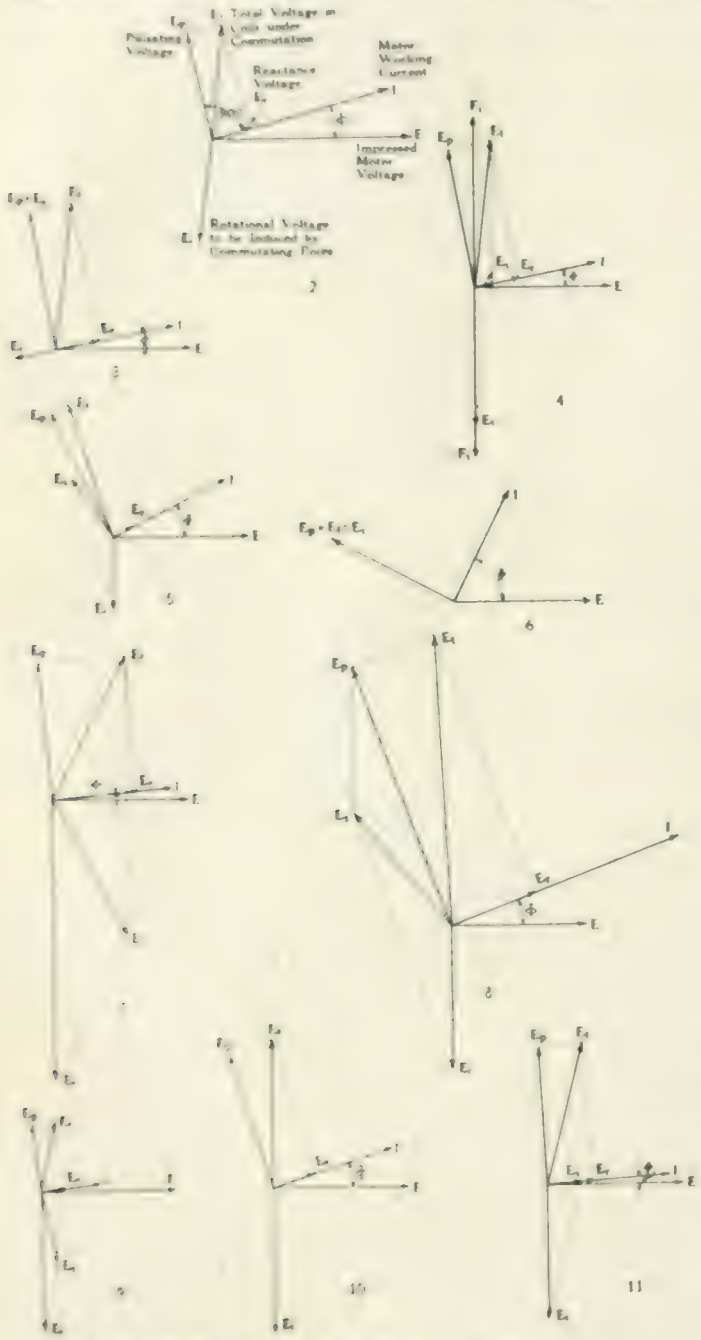


FIG. 1

Diagramatic sketch of single-phase motor showing the cross magnetic flux of the armature which is not compensated for by the compensating winding.

armature. Therefore, it may be considered that the armature conductors cut these leakage lines and, as a consequence, that an e.m.f. is induced in the conductors under commutation. In the case of any e.m.f. induced by conductors cutting a flux, the e.m.f. is in phase with the flux. Since this cross flux is nearly in phase with the armature currents, this e.m.f. will therefore be in phase with the main motor current, and will be taken into account in this way in the diagrams which are to be derived in connection with the discussion to follow.

Referring to Fig. 2, the vector E, represents the voltage impressed upon the motor. The working current of the motor I lags a certain angle Φ behind the impressed voltage of the motor.



FIGS. 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11
Vector diagrams showing the commutating voltages in the short-circuited armature coil of a single-phase series motor with shunt-connected commutating poles

As previously pointed out, the voltage induced by the cross leakage field in the coils under commutation is approximately in phase with the working currents, and will hereafter be referred to as the reactance voltage. This voltage may be represented by the vector *Er*, Fig. 2. If it be further assumed that the main field is in phase with the working current of the motor, which is nearly correct under the assumption that the short-circuit currents in the commutating coil are eliminated by the action of the commutating pole, we must represent the voltage induced by the fluctuations of the main field by a vector which is 90 degrees behind the current. This voltage will hereafter be called the "pulsating" voltage and is represented by the vector *Ep*. By combining the vectors *Ep* and *Er*, we obtain the total voltage *Et* induced in the short-circuited coils when no commutating poles are provided. It

is therefore evident that in order to make the resultant voltage zero the commutating poles would have to induce a voltage *Ei* in the coil under commutation equal and opposite to the voltage *Et*.

The question now arises as to how it is possible to induce a flux in the commutating poles which will give the desired voltage *Ei*. Let it first be assumed that the commutating pole is excited by the working current of the motor, as is customary in series direct-current machines. This would mean that the commutating pole send a flux through the armature which is in phase with the armature current, but opposite to the leakage fluxes. It would therefore be possible to induce a voltage in the coils undergoing commutation which is opposite to the voltage *Er*. It will readily be seen by reference to Fig. 3 that the best possible effect of a voltage of such phase would be to compensate and to eliminate the effect of the reactance voltage *Er*. This means that the total short-circuit voltage *Et* could be reduced to the voltage *Ep*. It would be utterly impossible to compensate for this remaining part of the short-circuit voltage, as *Er* and the counter-voltage *Ei*, Fig. 3, corresponding to it, are at right angles to *Ep*. Since the proportions assumed for the vectors are such as are frequently found in practice, it will be seen that a commutating pole with a series winding would do very little good in reducing the total voltage in the coil under commutation. In the present example the reduction is only about five percent.

A second possible way of connecting the commutating pole would be in shunt relation to the motor. In this case, the flux in the commutating pole would be about 90 degrees behind the impressed voltage *E*. This flux is represented by the vector *Fi*, Fig. 4. By reversing the currents of the commutating pole, this flux may be arranged to have the direction — *Fi*. This flux — *Fi* will now induce a voltage in the coils undergoing commutation (due to the rotation of the armature) which is in phase with this flux, and which may be represented by the vector *Ei*, Fig. 4. By providing for the proper value of current in the commutating pole winding, such conditions as are shown in the proportions of the vectors in Fig. 4 are obtained. It will be seen that the resultant of the voltages *Et* and *Ei*, that is, the remaining sparking voltage *Es* is very small, in fact, only about twelve percent of the original voltage *Et*. There is no doubt that a motor can be operated almost sparklessly with such a small resultant voltage, and therefore the motor performance will be very satisfactory

under these operating conditions, even without preventive resistance leads.

The question arises, however, as to whether the conditions will remain as favorable when the load of the motor changes. This question will be investigated by a number of diagrams which in principle are exactly the same as that of Fig. 4, except that such changes will be made as are found to exist when the load conditions are altered.

Let it be assumed first that the motor current remains the same, but that the motor is operated at lower voltage, and running at about one-half the speed. Fig. 5 shows the conditions which would then exist. Since the current is the same as in Fig. 4, the flux and the pulsating voltage *Ep* induced by it will be the same as in Fig. 4, as the frequency of course remains unchanged. The reactance voltage *Er* is proportional to the speed of the motor, and therefore one-half its former value. The same applies to the voltage *Et* induced by the commutating pole, if it be assumed that full voltage is impressed on the commutating pole winding, independently of the reduction in motor voltage considered in the present case. It is found that in this case the resultant voltage *Es* is as large as 53 percent of the voltage *Et* under the conditions assumed. In other words, the effect of the commutating pole is not nearly as beneficial as before. In fact, the commutating pole will have practically no effect whatsoever in the extreme case of reduced motor speed as at starting. This case is represented in Fig. 6. Since the armature speed is zero in this case, the voltages *Er* and *Es* are both zero while the voltage *Ep* remains the same as in Fig. 4 and is, at the same time, the total resultant and sparking voltage *Es*.

Considering now the other extreme, that is, the case in which the motor is running at a much higher speed than that assumed in Fig. 4, say, at about twice that speed; in this case, since the current and the main flux have been assumed to be the same, the voltage *Ep* remains the same, as in the previous case, while the voltages *Er* and *Et*, which are both proportional to the speed, are doubled. It will be seen that in this case, which is illustrated eventually in Fig. 7, the resultant sparking voltage is again very large—about 90 percent of the voltage *Et*. It follows, therefore, that while the scheme of using shunt-connected commutating poles is very effective for one given speed, its favorable effect decreases when the speed is either decreased or increased.

The conditions are also affected by any changes in the current. The case of wave-like current is represented by Fig. 8. If

it be assumed that the effect of the saturation is negligible, twice the current will mean twice as strong a main field, and a doubling of the voltage *Ep*. Since the flux in the commutating pole remains unchanged, the voltages *Er* and *Ei* will remain unchanged, if it be assumed further that the armature speed remains the same. The resultant sparking voltage in this case is about 55 percent of the voltage *Et*. Fig. 9 represents the opposite case of Fig. 8, that is, where the current is assumed to be one-half as large as in Fig. 4. In this case the voltage *Ep* is reduced to half the value shown in Fig. 4, while *Er* and *Ei* are unchanged. The resultant sparking voltage *Es* is in this case 102 percent of the voltage *Et*; this means that the operation is even slightly worse than it would be without commutating poles. It is evident, then, that changes in load current in the motor from a given value, such as assumed in Fig. 4, either up or down, will decrease the favorable effect of the commutating pole.

It will also be of interest to show the effect of varying the power-factor of the motor. The same conditions as in Fig. 4 are assumed for the case of Fig. 10, with the exception that the power-factor has been assumed to be lower. It will be seen that this has a favorable influence on the sparking voltage, insofar as it happens that, in this case, the resultant voltage *Es* is zero, which is of course the best possible condition. It is evident that a further decrease of power-factor would change this favorable condition, as it would lead to a resultant voltage in the opposite direction, as shown in Fig. 4. Fig. 11 shows a diagram assuming the same conditions as in Fig. 4, except with a better power-factor. It will be seen that this means an increased sparking voltage *Es* which is in this case about 24 percent of the voltage *Et*.

COMMUTATION UNDER PRACTICAL OPERATING CONDITIONS

When a compensated motor of the series commutator type with shunt-connected commutating poles is run under practical operating conditions, current, speed and power-factor change whenever the load condition changes, and all of the changes are to be taken into account in plotting the above diagrams. In the following a number of practical cases are worked out with diagrams in the same manner as that outlined above in connection with Figs. 2 to 11, inclusive, except that changes of current, speed, and power-factor are all taken into account at the same time in drawing the vector diagrams corresponding to the various load

conditions considered. Both the polar and rectangular systems of coördinates are used because, in these cases, the polar curve shows by its direction of curvature in which direction further corrections should be made, in order to approach more nearly the ideal operating conditions (as expressed by a straight line), while the rectangular curve gives a clearer conception of the actual corrective effect of the commutating poles as compared with non-commutating pole motors.

The resultant vectors for the sparking voltage are shown in Fig. 12 for a number of load points under the assumption that the motor, as well as the commutating pole, is connected to a constant voltage while the load changes. The values of the resultant sparking voltage are also shown in rectangular coördinates in Fig. 13. This curve also shows the resultant sparking voltage

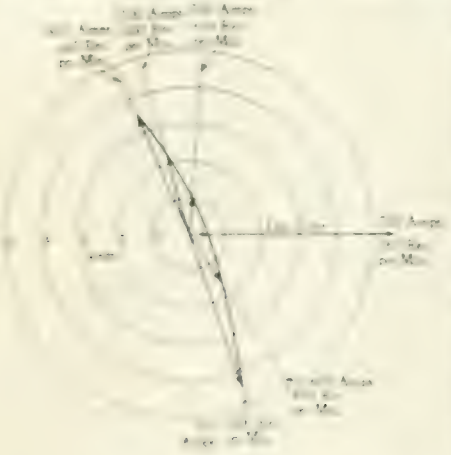


Fig. 12

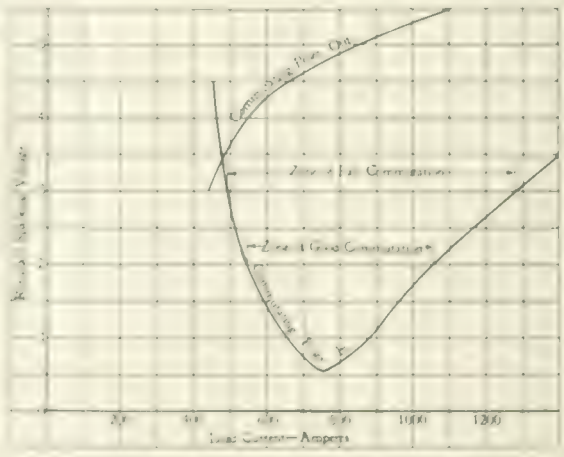


Fig. 13

Polar and rectangular representation of the resultant commutating voltage of a single-phase series motor with shunt-connected commutating poles. Motor voltage constant; load and speed varied.

which would exist if there were no commutating pole. It will be seen that the commutating pole is beneficial over a large range of load conditions. It improves the commutation for all loads above 475 amperes. Under the assumption that the motor is built without resistance leads, it will operate very satisfactorily for load currents between 540 amperes and 1 050 amperes, since, when the resultant voltage is no more than about two volts between commutator segments, quite satisfactory commutation is usually obtained. The operation of the motor will be fair between load currents of 490 amperes and 1 280 amperes, while for load conditions outside of this range the commutation will be rather unsatisfactory. The motor will, of course, *operate* with a resultant sparking voltage larger than three volts, and momentary loads outside of the range

given above may be permitted without danger to the motor; but the operation of the motor for these load conditions would not be advisable for any length of time.

Instead of operating the motor on a constant voltage, it is frequently desirable in practice to vary the motor voltage in order to get either variable speed with constant load torque, or to get constant speed with the varying load. If this is done, the commutating pole can be connected in two different ways. It can either be connected to constant voltage, while the motor voltage is changing, as shown in Fig. 14, or it can be connected in parallel with the motor, that is, in such a manner that its voltage changes with the motor voltage, as shown in Fig. 15.

Resultant vectors for sparking voltage are shown in Fig. 16 under the assumption that the motor is connected as in Fig. 14 and

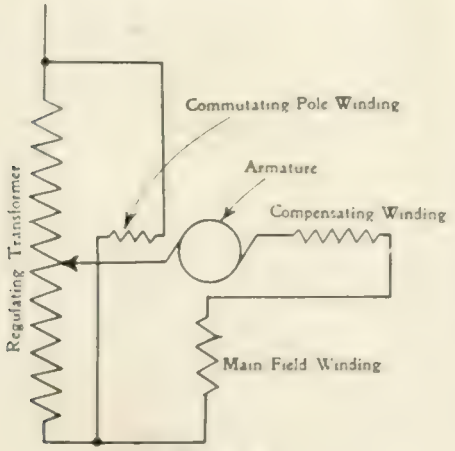


FIG. 14

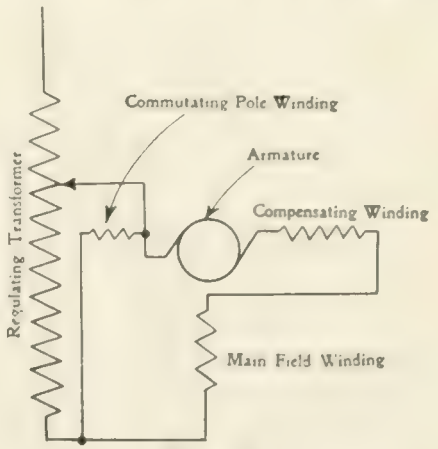


FIG. 15

Connections of single-phase series motor with shunt-connected commutating poles.
Fig. 14—Constant voltage applied to commutating pole
Fig. 15—Commutating pole voltage varies with motor voltage

that the load torque is constant, while the speed is varied. Fig. 17 shows the resultant sparking voltages for this case in rectangular coördinates. It also shows again the sparking voltages which would exist without the action of the commutating pole. Also, in this case, the commutating poles are very beneficial for a large range of speed. It will be seen from the figure, that the motor will operate well for speeds between 440 r.p.m. and 980 r.p.m., and it will operate fairly well at speeds between 300 r.p.m. and 1 125 r.p.m. Figs. 18 and 19 show the results obtained for the same load conditions but with the motor connected as in Fig. 15. It will be seen that good operation can be obtained in this case for speeds between 525 r.p.m. and 925 r.p.m. and fair operation will be obtained for speeds between 350 r.p.m. and 1 000 r.p.m. Comparison between

Figs. 17 and 19 shows that under the assumed load condition of constant load and variable speed, the connections of Fig. 14 are more favorable than those of Fig. 15.

Resultant vectors for sparking voltage are shown in Fig. 20 under the assumption that the motor is connected as in Fig. 14, and under the assumption that it is to be operated at constant speed while the load torque changes. Fig. 21 shows the resultant

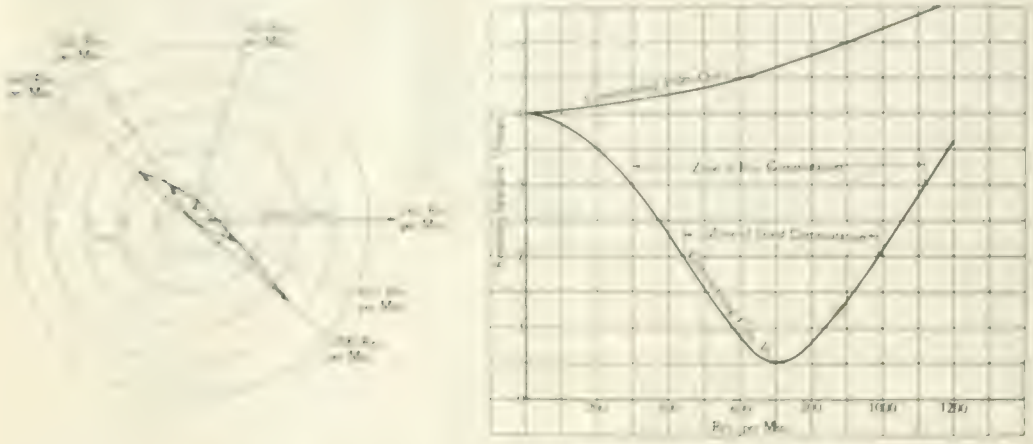


Fig. 17

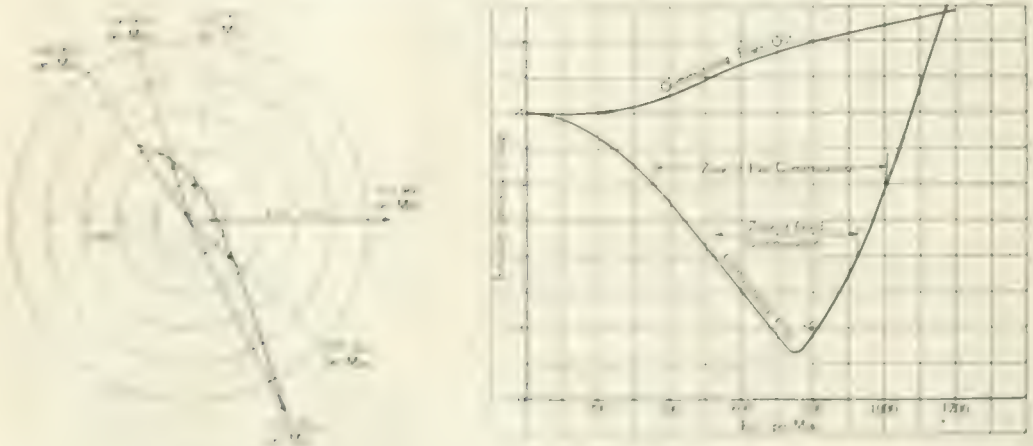


Fig. 19

sparking voltage for this case in rectangular coördinates; the resultant sparking voltage under the assumption of no commutating pole is also given. Good commutation will be obtained in this case for all currents between 360 and 1 120 amperes, while the motor will commutate fairly well for loads between 240 and 1 400 amperes. Figs. 22 and 23 show the results obtained for the same load condi-

tions, but with the motor connected as per Fig. 15. In this case, good commutation will be obtained over the entire range of load conditions shown on the curve. It follows therefore that, for the case of constant speed with variable load, connection as in Fig. 15, is very advantageous.

It will be seen that the advisability of using commutating poles connected in shunt without using resistance leads in the armature depends entirely upon the load conditions of the motor



FIG. 20

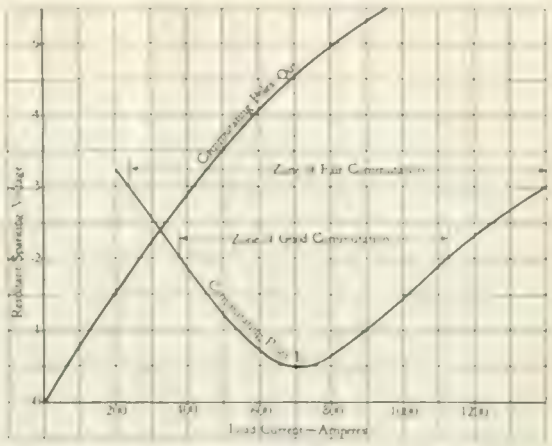


FIG. 21

COMMUTATING POLE VOLTAGE CONSTANT

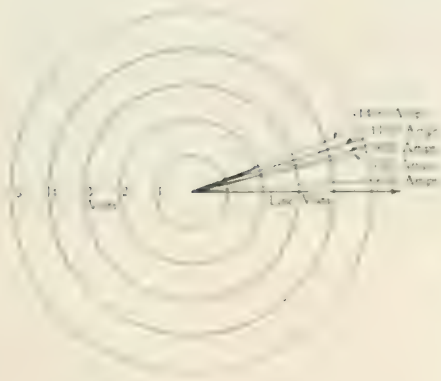


FIG. 22

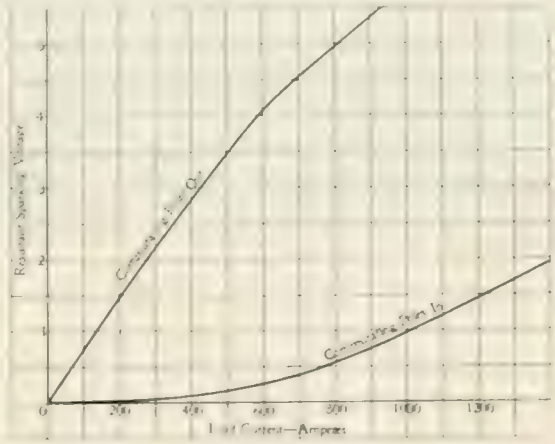


FIG. 23

COMMUTATING POLE VOLTAGE VARIED WITH MOTOR VOLTAGE

Polar and rectangular representation of the resulting commutating voltage of a single-phase series motor with shunt connected commutating poles. Speed constant, load torque varying.

and that, while under certain conditions it is quite feasible and advisable to employ commutating poles in preference to resistance leads, this is not the case under other conditions of load. The advisability of using commutating poles with or without resistance leads in the armature for railway work, will be considered in a later discussion in connection with the description of some other types of motors.

SOME INTERESTING APPLICATIONS OF THE OSCILLOGRAPH

H. B. GALLEHER

USES for the oscillograph have multiplied rapidly during the last few years. Companies which formerly considered themselves fortunate in having one oscillograph now make use of three or four in connection with experimental and commercial testing work. It is now common practice to make records showing wave shapes, current and voltage values, and other electrical phenomena both recurring and transient; but it is probable that comparatively few realize to what extent the oscillograph is being used to facilitate the development of new apparatus. Its usefulness to the designing

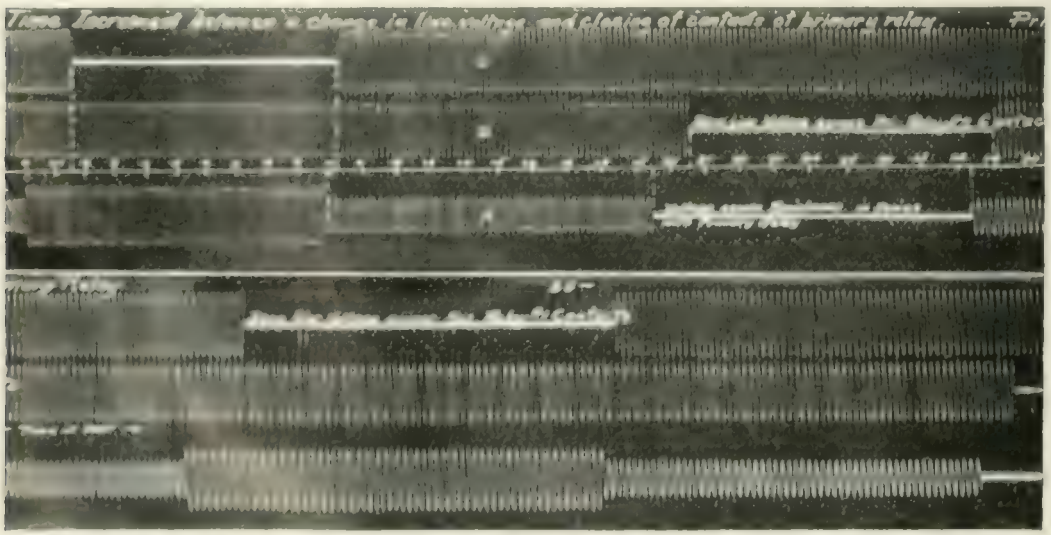


FIG. 1—TWO ADJACENT SECTIONS OF AN OSCILLOGRAPH RECORD SHOWING TIMING OF OPERATION OF THE TWO PRIMARY CONTACTS OF A POTENTIAL REGULATOR RELAY UNDER TEST

A indicates oscillations of normal, low and high voltage on primary relay.
B indicates time of closing and opening of primary relay contacts No. 2, which operate in case of high line voltage.
C indicates time of closing and opening of primary relay contacts No. 1, which operate in case of low line voltage.

engineer for obtaining design data may be illustrated by a few striking examples, in which without its use it would have been necessary to resort to a very long cut-and-try process.

For example, assume that a potential regulator with automatic control is to be developed such that, when the voltage across the main line, to which it is connected, is changed, such change will operate a primary relay, which in turn will operate a secondary relay controlling a motor used to operate the movable element of the

regulator, so that it will add to, or subtract from the main line voltage by such an amount as to bring this voltage back to a predetermined fixed value. When the voltage has reached its proper value after the regulator has corrected for the original change, the motor must be stopped very quickly to prevent the regulator from carrying the voltage beyond normal in the opposite direction, a condition which requires a quick action, electrically operated brake. The complete cycle of operations must be accomplished in a minimum increment of time and, as the relay itself takes an appreciable time to operate after a change in voltage has occurred, it is important to in-

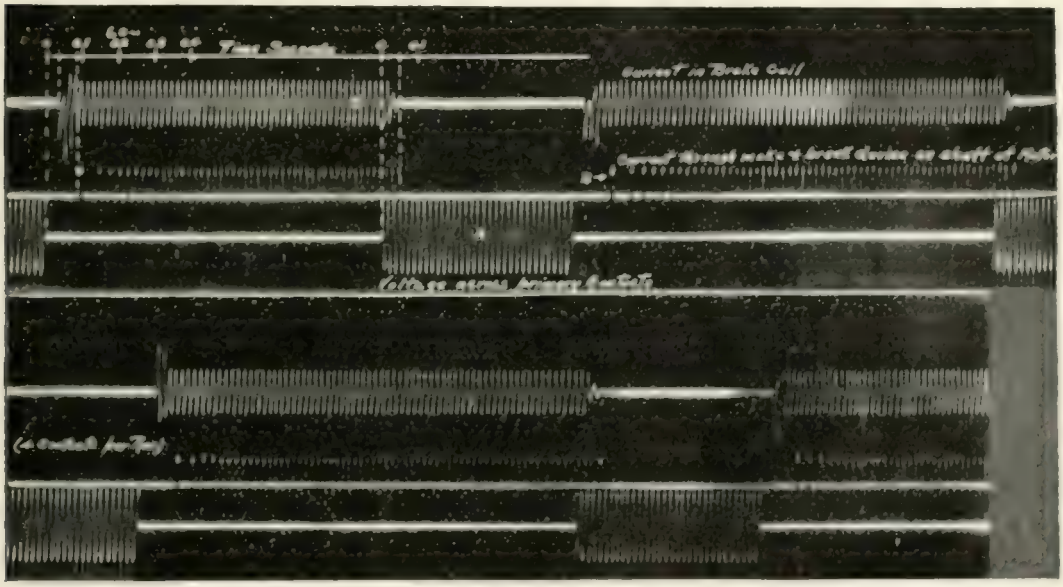


FIG. 2—TWO ADJACENT SECTIONS OF AN OSCILLOGRAPH RECORD SHOWING TIME INCREMENTS BETWEEN OPERATION OF PRIMARY RELAY AND STARTING AND STOPPING OF REGULATOR MOTOR

A indicates voltage across primary contacts; voltage is zero when contacts are closed.
B indicates rate of acceleration and braking of motor.
C indicates current in brake magnet coil. Brake released when current is flowing.

vestigate the respective steps in the cycle. The oscillograph is admirably adapted for measuring such increments of time.

Oscillograms taken on such a cycle of operations are shown in Figs. 1 and 2. In order to simplify the test for timing the operation of the primary relay contacts with changes in voltage, the circuits were so arranged that, instead of main line voltage being applied to the primary relay, as in the ordinary operation of the regulator, an auxiliary voltage was applied, and two sections of resistance, arranged with short-circuiting switches, were connected in series in this circuit. With one section of resistance short-circuited

the relay received a voltage corresponding to normal; with both sections short-circuited, the voltage on the relay corresponded to a two percent increase; while, with all resistance in, the voltage received by the relay corresponded to a two percent decrease of main line voltage, the relay having been set to operate on a minimum change of two percent above or below normal. Such a relay can be adjusted for larger or smaller changes in voltage, according to the requirements of the service for which the regulator is to be installed. Records *C* and *B* of Fig. 1 show the action of the relay contacts, Nos. 1 and 2, corresponding to "low" voltage and "high" voltage, respectively. The relay was caused to operate by closing and opening the resistance short-circuiting switches by hand. Record *A* indicates the voltages across the resistance which thereby indicates the corresponding voltage applied to the primary relay, as explained above. Zero voltage on record *A* of course means that the resistance was short-circuited, while zero voltage on records *C* and *B* means that the corresponding relay contacts were closed. As 60 cycle alternating current was applied simultaneously across the relay contacts and the resistance, and each of these auxiliary circuits was connected through one of the three elements of an oscillograph, the basis for timing the operations is evident. The time scale was drawn on the film after it had been developed, as a matter of convenience in reading the records.

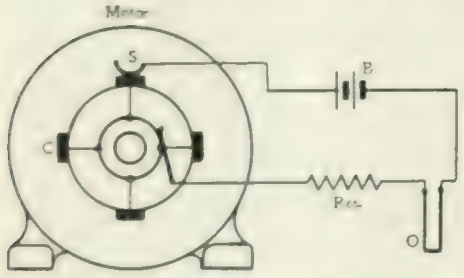


FIG. 3—CONNECTIONS FOR TEST RESULTS IN FIG. 2

At the extreme left of Fig. 1, record *A* indicates a condition of normal voltage (i. e., one resistance switch closed), and hence, relay contacts *1* and *2* are open. At the point 0.0 on the time line the resistance switch is opened, corresponding to a decrease in line voltage. In about 0.16 seconds after this decrease the primary relay closes, as shown on the *C* record. At the end of 1.02 seconds the main line voltage is increased to its former (normal) value by the operator running the test, and the relay opens in about 0.03 seconds. At the end of 1.94 seconds the voltage on the relay is increased by short-circuiting all of the resistance, and contact No. 2 of the primary relay, which responds to high main line voltage, then closes in a time increment of about 0.11 seconds, as shown on record *B* of Fig. 1.

The time increments between the opening and closing of the primary relay and the starting and stopping of the motor which operates the regulator are shown in Fig. 2. The motion of the motor is recorded by means of a make-and-break device arranged and connected as shown in Fig. 3, *C* being the contact maker on the shaft of the motor, *S* the spring contactor, *O* an oscillograph element, and *B* a battery. As arranged, the contact maker makes and breaks the battery circuit through the oscillograph four times every revolution of the motor shaft. Record *C* of Fig. 2, shows the current in the electrically operated brake which holds the motor locked when the primary relay is open and unlocks the motor when the relay is closed. This record shows then, that there is a time increment of less than 0.1 seconds between the closing of the primary delay and the starting of the motor. It also indicates that the motor gets up to

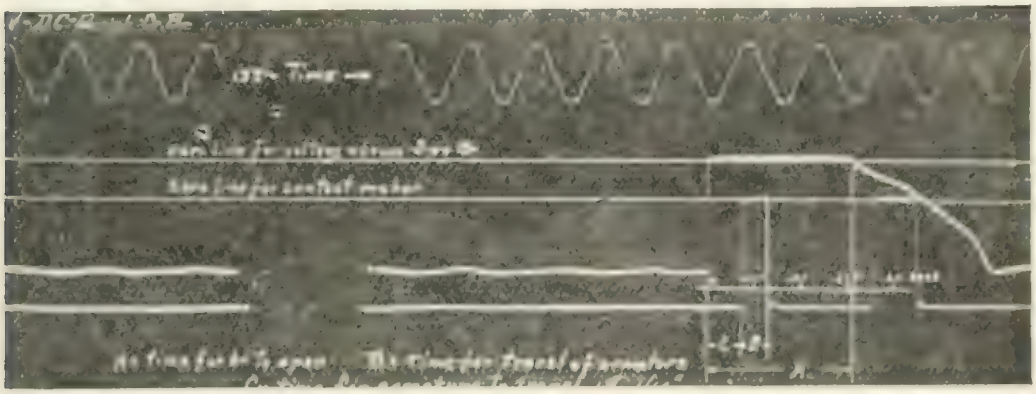


FIG. 4.—OSCILLOGRAPH RECORD OF TEST ON CYCLE OF OPERATION OF CIRCUIT BREAKER MECHANISM

Section of long film covering several cycles. The end of the last cycle is shown at the left of the record.

speed in about 0.1 second, and that after the relay is opened it takes a little less than one revolution to stop the motor. The time increments shown in these two records are affected more by the mechanical features of the apparatus than by the electrical features; thus it is that the oscillograph comes to the aid of the mechanical as well as the electrical designer.

Again, in circuit breaker development, the oscillograph can be used very effectively. Its use in such work is illustrated in the oscillogram of Fig. 4. While circuit breaker oscillograms are probably more common than others, yet because of the short increments of time indicated in connection with the operation of this particular circuit breaker, this record affords an especially interesting example of the point in view. An arrangement of circuits for timing the operation of a direct-current circuit breaker by means of oscillograph records is shown in Fig. 5. When the film was first exposed

the switch *S* of Fig. 5 was open and the circuit breaker *C*, under test, was closed, as indicated at *O* on the time line, Fig 4. The basis for timing was obtained by applying 133 cycle alternating current to one element of the oscillograph, as shown in this figure. In about 0.003 of a second after closing switch *S* of Fig. 5 the circuit breaker armature began to move; in about 0.006 seconds it had traveled its full length and tripped the circuit breaker; in a little over 0.015 seconds the circuit breaker started to open, and in about 0.03 seconds it had completely opened. By means of this record it can be determined whether the first 0.006 second is consumed mostly by the movements of the mechanical parts of the breaker or by the magnetic circuits in getting these mechanical parts in motion. In the present case the object which the engineer had in view was a quick action breaker to operate on high voltage direct current, and the oscillograph served as a chronograph to give both the total time of

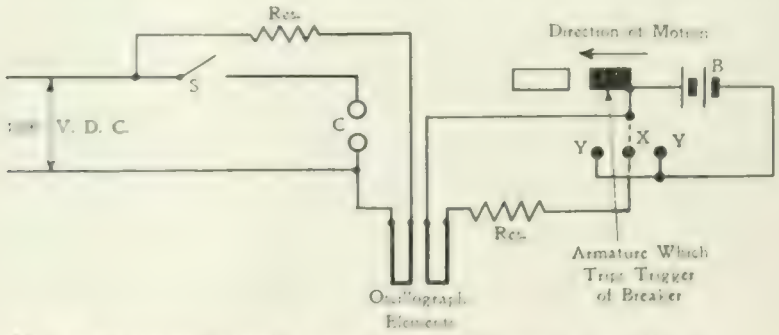


FIG. 5—CONNECTIONS FOR TEST RECORDED IN FIG. 4
The 133 cycle timing circuit is not shown.

operation of the circuit breaker and the time increments of the different motions involved in its complete operation.

The oscillograph of Fig. 6 shows the operating cycle of a motor-driven, automatically controlled planer working under severe conditions. In this record the first two seconds of time are consumed in reversing the motor so as to bring the table from a return to a forward motion. The forward motion continues for about one second before the cutting tool strikes the work, and at this point the voltage drops slightly, while the current increases from 12 to 120 amperes. At the end of the fifth second the tool is seen to have completed its cut, whereupon the motor runs light for about one second, when it again reverses. The table is again returned and reversed, and at 11.5 seconds the tool is again making its full cut. In this film the time is recorded by opening the oscillograph voltage wave once every five seconds, for a short interval of time. By using a long film a

record of several successive cycles covering a period of perhaps five minutes can be obtained, thus giving a check on any one cycle. In this manner, accurately recorded characteristics of such machines can be obtained and kept on file for reference, for such an oscillogram will interest not only the designing engineer and the power house operator, but also the shop manager. The designing engineer is of course especially concerned with the question of motor current, peaks, etc., at various steps of the cycle of operation; the power house operator is interested in determining from the current curves the average power required for the complete cycle, as well as the nature of the load, i. e., whether it is intermittent, with heavy peaks, or of uniform characteristics; the shop manager in turn determines by an examination of the record whether the machine is being operated at its highest efficiency by reducing to a minimum the time interval required for each step of the cycle, without introducing operating difficulties such as might result if, for example, the tool were allowed to start on a cut while the motor was still drawing a heavy starting current.

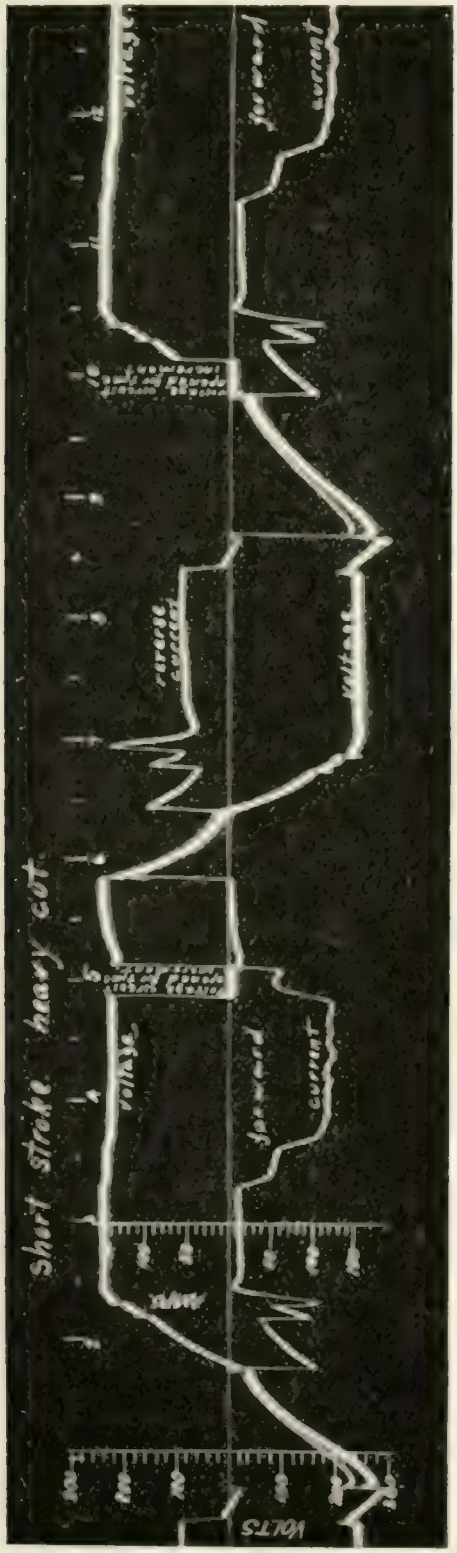


FIG. 6—OSCILLOGRAPH RECORD OF CYCLE OF OPERATION OF MOTOR DRIVEN PLANER
Section of long film covering several cycles of operation.

In the preliminary stages of development work where many observations are required and the finer degrees of precision are not

necessary, the tracing table attachment of the oscillograph may be used to good advantage. A good example of such work is found in connection with the development of an ignition system for gas engine work. An oscillograph tracing of this kind is shown in Fig. 7. To obtain this record a flexible shaft was inserted between the gas engine drive and the mechanism which was driving the oscillating mirror of the oscillograph tracing table. In this way pencil drawings were taken of the primary and secondary currents in the spark coil as shown in Fig. 7. The current curves show at what point of the primary current the interrupter opened the circuit, and also give time

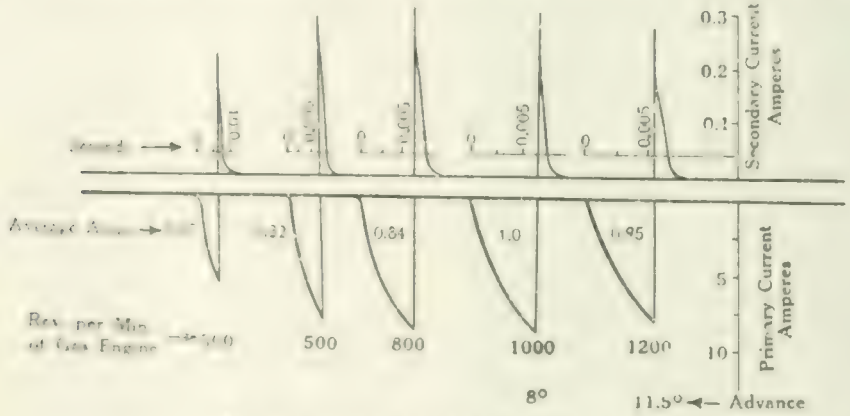


FIG. 7—GAS ENGINE IGNITION

increments. An arrangement was also used to show the advance in the spark as the speed of the engine increased. A complete history of the behaviour of the entire ignition system, including the time-element and maximum current values of the spark coil, the action of the interrupter, and the automatic spark advancing mechanism, together with speeds and time increments is given by this record. This tracing was readily taken in a very short time and was, in fact, one of the first steps in the development which served as a starting point for more complete design work on the apparatus in question. The performance of the final completed apparatus was later recorded on a long photograph film.

PHASING OUT POLYPHASE CIRCUITS

HAROLD W. BROWN and S. S. NEU

INTRODUCTORY

CERTAIN conditions are necessary in order to connect a synchronous machine in parallel with a system already in operation. The fundamental condition is that the electromotive forces of the incoming machine and of the system to which it is to be connected shall be approximately the same at each instant. This means that the two frequencies must be the same; that the voltages, as measured by a voltmeter, must be equal, and that the two voltages must be in phase. In polyphase machines it is necessary that these conditions obtain for each phase, which requires that the sequence of phases be the same in both machines. If an attempt at parallel operation is made under any other conditions there will be interchange of currents between the machine and the system, which may lead to disastrous results.

Alternating-current machines are said to be in synchronism when they agree in the particulars stated, and the operation of adjusting the incoming machine to the system is termed "synchronizing." Various synchronizing devices are employed for determining when the proper conditions for parallel operation are obtained. The elementary principle employed in determining when generators are at the same frequency and in phase is illustrated by Fig. 1, in which *A* and *B* represent two single-phase generators, the leads of which are connected to the bus-bars by switches *C*, and two series of incandescent lamps are connected as shown. It is evident that as the electromotive forces change from the condition of phase coincidence to that of phase opposition, the flow of current through the lamps varies from a minimum to a maximum. When the electromotive forces of the two machines are exactly equal and in phase, the current through the lamps is zero. As the difference in phase increases, the lamps light up. They increase to a maximum brilliancy when corresponding phases are in exact opposition. From this condition the lamps will decrease in brilliancy until completely dark, indicating that the machines are again approximately in phase. The rate of pulsation of the lamps depends upon the difference in frequency, (i.e., upon the relative speeds) of the machines. By adjusting the speed of the incoming machine the pulsation can generally be reduced to as

low a rate as desired before throwing the switch that connects the machine in parallel with the system.

When the voltage is too high for any of the synchronizing apparatus, it is usual to place voltage transformers between the main circuits and the synchronizing circuits, to reduce the voltage to the desired amount. The elementary diagram then takes the form shown in Fig. 2.

In the case of polyphase machinery, the connections should be so made to the switches that when one phase is in synchronism all the other phases are also. After this is accomplished it is obviously unnecessary to synchronize more than one phase. To obtain this correspondence of phases it is necessary to "phase out"—that is, to test the two circuits to see that when one pair of leads of one circuit is in phase with a corresponding pair of the other circuit, all corresponding leads of the

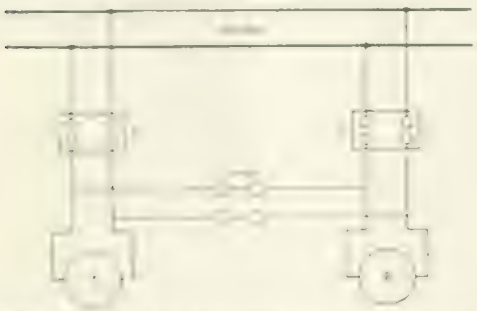


FIG. 3—ELEMENTARY CONNECTIONS FOR LOW-VOLTAGE SINGLE-PHASE SYNCHRONIZING

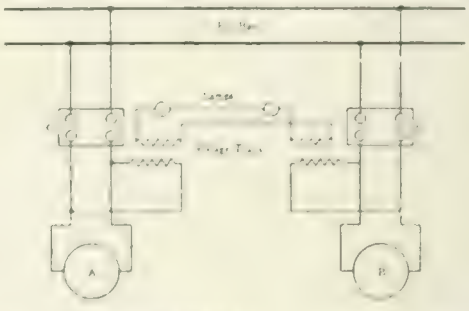


FIG. 2—ELEMENTARY CONNECTIONS FOR HIGH-VOLTAGE SINGLE-PHASE SYNCHRONIZING

two circuits are in phase and may be connected together. After the circuits are phased out, it is necessary only to synchronize one phase *provided the main connections are not changed*. If they are subject to change the circuits should be phased out whenever the switches connecting them are to be closed.

DIRECTIONS FOR PHASING OUT

Single-Phase—It is obviously unnecessary to phase out a single-phase circuit; as there is only one pair of leads for each circuit, it is simply necessary to bring this pair in phase, that is, to synchronize.

Two-Phase—Four-Wire—First determine the two leads of each phase, by means of a voltmeter; the leads that have the normal voltage of the circuit between them are leads of the same phase. Make connections as shown in Fig. 3 if voltage transformers are used, or as shown in Fig. 4 if voltage transformers are

not used. If transformers are not used the total voltage of the lamps in each line should be approximately the same as the voltage of the circuit; for example, for 440-volt circuits, two 220-volt or four 110-volt lamps are required in each line.

The connections of Fig. 3 may be modified so as to be similar to Fig. 7 *b* below, which pertains to three-phase connections, but for two-phase circuits this does not reduce the number of necessary transformers. The connections may be made similar to Fig. 7 *c*, (but with two short-circuiting connections instead of one) provided the transformers will stand double the line voltage for a short time and the two phases are not interconnected on *both* sides of the switch. In making this connection be sure that the two short-circuiting connections are not on the same phase.

The connections of Fig. 4 may be modified by providing double the number of lamps on one pole of each phase, omitting

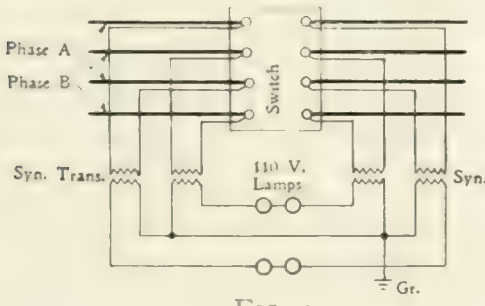


FIG. 3

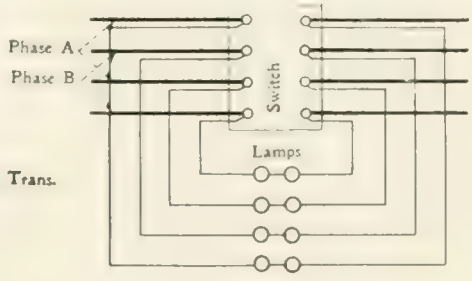


FIG. 4

CONNECTIONS FOR PHASING OUT TWO-PHASE—FOUR-WIRE CIRCUITS, WITH AND WITHOUT USE OF TRANSFORMERS

Fig. 3 may be modified to correspond to Fig. 7 *a* or 7 *b*.

the lamps on the other poles, and completing the circuit by closing two poles of the switch, or connecting wires across those poles. This connection should not be used if the two phases are interconnected on both sides of the switch, because a short-circuit between phases would be produced when the two circuits are not in phase. If there is a ground on both sides of the switch and wires are used in phasing out for closing two poles of the switch, they should be heavy enough to carry the ground current.

Run the incoming machine at about synchronous speed and normal voltage. If the lamps do not all become bright and dark together, interchange the main leads of one phase on one side of the switch, leaving the lamps connected to the same switch terminals, after which the lamps should all fluctuate together, indicating that the connections are correct. The machines are in phase when all the lamps are dark.

Two-Phase—Three-Wire—First determine which is the common wire of each circuit, by means of a voltmeter. The voltage between the common wire and each of the others is the same, and is the rated voltage of the circuit. The votage between the other two wires is 1.41 times the rated voltage. Make connections as shown in Fig. 5 if voltage transformers are used, or as shown in Fig. 6 if voltage transformers are not used. The arrangement

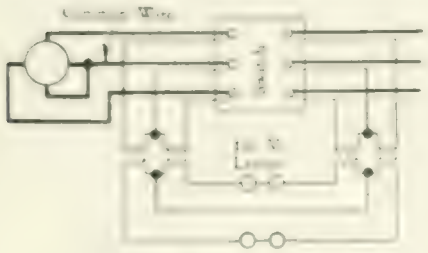


FIG. 5

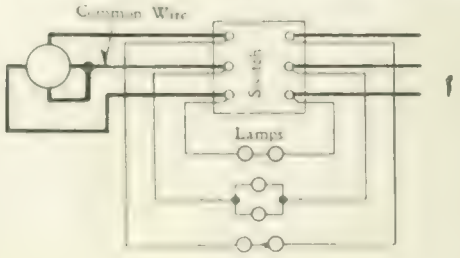
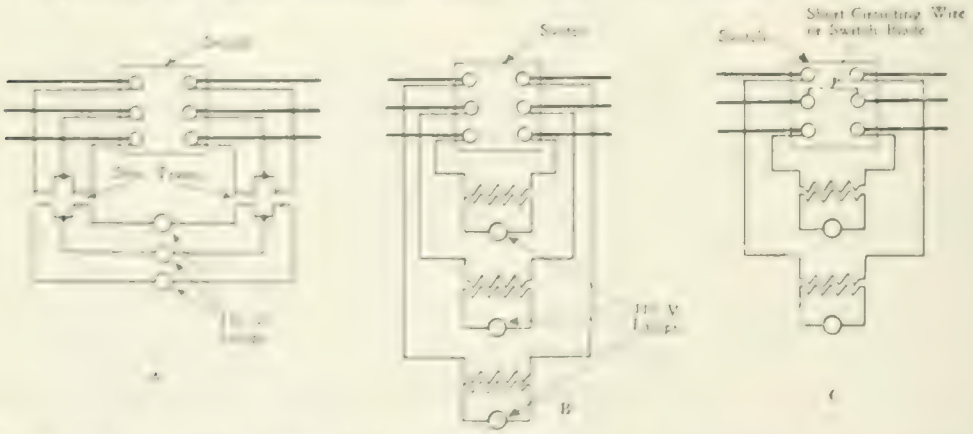


FIG. 6

CONNECTIONS FOR TESTING OUT TWO-PHASE—THREE-WIRE CIRCUITS

shown in Fig. 7*c* may also be used for two-phase—three-wire circuits, if the conditions are as mentioned with reference to that diagram. If Fig. 6 is used the total voltage of the lamps in each outside line should be double the voltage of the circuits; for example, for 440-volt circuits, four 220-volt or eight 110-volt lamps are required in each outside line. The two lamps in parallel in



FIGS. 7 (A), (B), AND (C)—CONNECTIONS FOR TESTING OUT THREE-PHASE CIRCUITS WITH THE USE OF TRANSFORMERS

Fig. 7*a* may be modified to correspond to Fig. 5.

the middle line are to prevent a possible short-circuit through ground; they do not become bright, and their effect on the brilliancy of the other lamps is hardly appreciable except where there is only one 110-volt lamp in each outside line, in which case the voltage is reduced about 20 percent. The lamps on the middle line may be omitted if it is desirable to connect the two middle lines directly together.

Run the incoming machine at about synchronous speed and normal voltage. If the lamps do not all become bright and dark together, interchange the outside main leads on one side of the switch, leaving the lamps connected to the same switch terminals, after which the lamps should all fluctuate together, indicating that the connections are correct. The machines are in phase when all the lamps are dark.

Three-Phase—Make connections as in Figs. 7 *a*, *b*, or *c*, (or Fig. 5) if voltage transformers are used, or, as in Fig. 8 if voltage transformers are not used. In Fig. 8 the total voltage of the lamps in each line should be approximately the same as the voltage of the circuits; for example, for 440-volt circuits, two 220 volt or four 110 volt lamps are required in each line. The connections in Fig. 7 *b* put the same voltage on the transformers and lamps as Fig. 7 *a*. It is not suitable for a permanent connection, because it leaves both sides of the switch alive when one side is connected to a source of power. Its advantage is that it requires only three instead of four transformers. Fig. 7 *c* is similar to 7 *b*, but has only two transformers. The remaining transformers must be capable of standing double the line voltage for a short time, and the voltage on the lamps is correspondingly high. When this connection is used, if there is a partial ground on both sides of the switch the connection across the middle phase must be heavy enough to carry the ground current.

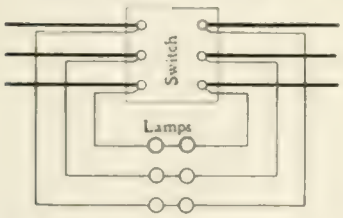


FIG. 8—CONNECTIONS FOR PHASING OUT THREE-PHASE CIRCUITS WITHOUT TRANSFORMERS

Run the incoming machine at about synchronous speed. If the lamps do not all become bright and dark together, interchange any two of the main leads on one side of the switch, leaving the lamps connected to the same switch terminals, after which the lamps should all fluctuate together, indicating that the connections are correct. The machines are in phase when all the lamps are dark.

Six-Phase Diametrical—As this connection is used almost exclusively for rotary converters, the voltage of which is low, no transformers are shown in the scheme shown in Fig. 9. The total voltage of the lamps in each lamp circuit should be approximately double the diametrical voltage of the rotary converters. If it is desired to use the voltage transformers, their primaries

should be capable of standing double the diametrical voltage for a short time and should be connected according to Fig. 9 between switch terminals *5* and *2*, *3* and *6*, and *1* and *4*, respectively. Connect a 110 volt lamp (or 220 volt if the transformer rated primary voltage is much less than double the diametrical voltage) in the secondary of each transformer.

First separate the six transformer leads into two groups having one lead from each power transformer in each group. If necessary, test by ringing out or lighting out, and mark each lead. The test should show that all the leads in one group are insulated from each other. If convenient, see that all three leads in one group connect to corresponding terminals of the transformers. But this is not essential, if it cannot be determined readily. A later test will show whether the connections are right or not.

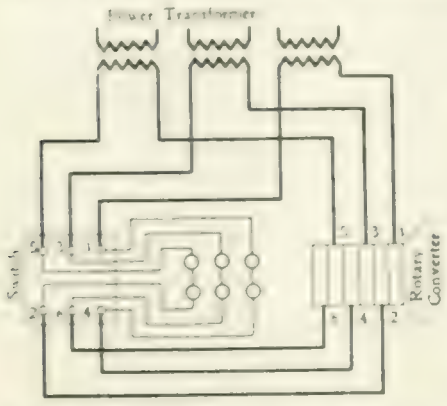


FIG. 9—CONNECTIONS FOR PHASING OUT SIX-PHASE, DIAMETRICAL CIRCUITS

Connect all the leads in one group to one set of the rotary converter brush terminals, Nos. *1*, *3* and *5*.* Connect the leads in the other group to the upper switch studs as shown in Fig. 9. Connect the other three rotary converter terminals to the lower switch studs as shown. Connect lamps between opposite switch terminals. Test the connections by lifting all the alternating-current brushes, closing the switch, and ringing out or lighting out the circuits between rotary converter terminals *1* and *4*, between *3* and *6* and between *5* and *2*. (The test should indicate continuity of each of these circuits). Put down brushes and open switch. With the rotary converter run-

*The representations of rotary converters, for both diametrical and double-delta connections given in Figs. 9 and 10, are on the assumption that the tap connections to the successive rings are electrically 60 degrees apart in phase. If machines have special connections to the rings, the equivalent angles may be readily determined by means of a voltmeter. When the machine is excited to its normal voltage the voltage between successive rings is one half the diametrical voltage (71 per cent of the direct-current voltage). Starting with the alternating-current brush at one end (call it No. 1), measure the voltage between No. 1 and the other brushes, and find one of the two brushes giving this voltage reading is the lowest of all the voltages measured. Call this brush No. 2. And find what other brush gives the same voltage between it and No. 2. Call this No. 3 and proceed as before. After finding No. 6, as a check, see that the voltage from No. 6 to No. 1 is the same as between No. 1 and No. 2. Use numbers of brushes corresponding to the numbering in Figs. 9 and 10.

ning at about synchronous speed and normal voltage the lamps may fluctuate in any one of four ways, as follows:—

1—All Lamps are Bright and Dark Together—No change in connections is necessary. The machine is in phase when the lamps are dark.

2—The Fluctuations of the Three Lamp Circuits Follow Each Other at Regular Intervals—This indicates reversal of phase rotation. Interchange at the rotary converter terminals the leads connected to *1* and *3* and those connected to *4* and *6*; or, if more convenient, interchange any two primary (three-phase) leads to the transformers. In either case, condition *1* should then obtain.

3—Two Lamp Circuits Fluctuate Together and the Third is Exactly Opposite in its Fluctuations—This indicates reversal of a transformer secondary. Interchange the leads of the transformer connected to the lamp circuit that differs from the other two. Condition *1* should then obtain.

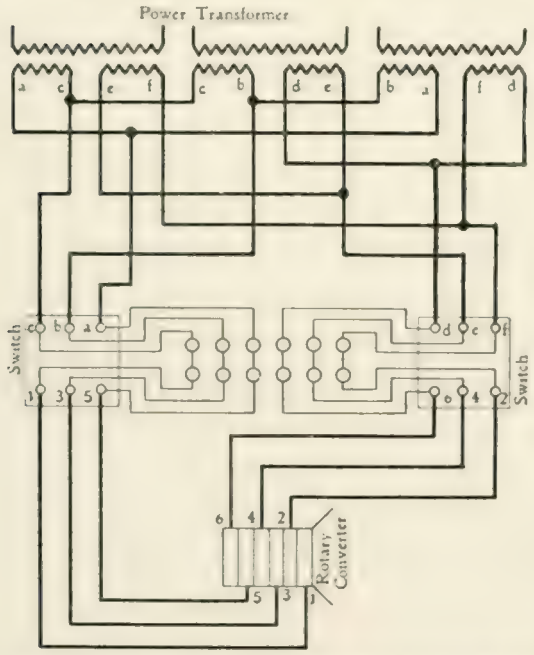


FIG. 10—CONNECTIONS FOR PHASING OUT SIX-PHASE, DOUBLE DELTA CIRCUITS

4—The Three Lamps Become Bright in Rapid Succession Then Pass Through an Interval in Which All the Lamps are Dim—This indicates a combination of reversals *1* and *3*. Interchange the leads to the transformer connected to the lamp circuit that fluctuates *between* the other two. Also interchange at the rotary converter terminals or at the switch terminals the leads connected to *1* and *3* and those connected to terminals *4* and *6*. Condition *1* should then obtain.

If the lamps act in any other manner than those described, there has evidently been an error in connecting. The connections should be traced out again by means of Fig. 9.

Six-Phase—Double-Delta—As with the six-phase diametrical connection, voltage transformers are usually unnecessary. The total voltage of the lamps in each line should be approximately equal to the voltage of either delta of the rotary converter. If it is desired

to use voltage transformers, each delta should have transformers the same as for one of the methods for three-phase, as in Fig. 7, *a*, *b*, or *c*. This requires a total of four, six, or eight transformers.

First connect the power transformer secondaries into a double-delta connection, as per Fig. 10. Connect the leads from one delta to the upper studs of one switch, and the leads from the other delta to the upper studs of the other switch. Connect lower leads of each switch to one group of rotary converter terminals, one to Nos. *1*, *3* and *5*,* and the other to Nos. *2*, *4* and *6*. Connect lamps between each pair of switch studs, as shown in Fig. 10. Test out the connections by lifting all the alternating-current brushes and ringing out. The test should show that *1*, *3* and *5* are electrically connected, and *2*, *4* and *6* also, but that *1*, *3* and *5* are insulated from *2*, *4* and *6*. With the rotary converter running at about synchronous speed and normal voltage the lamps may fluctuate in any one of three ways.

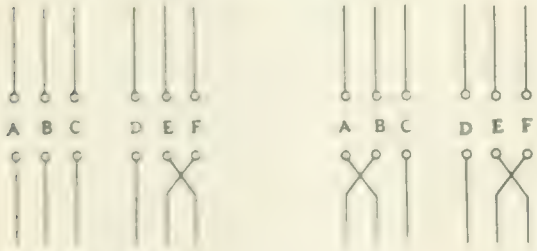


FIG. 11 FIG. 12

METHODS OF REVERSING CONNECTIONS TO OBTAIN PROPER SEQUENCE OF PHASES

1—All Lamps are Bright and Dark Together—No change in connections is necessary.

2—All in One Delta Fluctuate Together and Those in the Other Delta Follow Each Other at Regular Intervals—In the delta in which the lamps fluctuate together, the fluctuations occur at the same time as in one lamp circuit in the other delta. The main leads to which this circuit is connected are correct. The main leads to which the other two circuits are connected should be interchanged at one side of the switch (or at the corresponding rotary converter terminals). For example, if the lamps connected to *A*, *B*, *C*, and *D*, Fig. 11, fluctuate together and *E* and *F* differ, leads *E* and *F* should be interchanged as shown. Condition 1 should then exist.

3—All in Each Delta Follow Each Other Regularly—It will be observed that the fluctuations occur in pairs; each circuit of one delta becomes bright with a corresponding circuit of the other delta. Select any two circuits in which the fluctuations occur together,

*See Foot Note, p. 442.

and leave the main connections to this phase unchanged. Interchange the other two main leads of each delta at one side of each switch (or at the rotary converter). For example, if *C* and *D*, Fig. 12, fluctuate together, interchange leads *A* and *B* and leads *E* and *F*, as shown. If it is preferable to make the change in the three-phase circuit, interchange any two primary (three-phase) leads to the transformer. Condition *1* should then exist.

If the lamps act in any other manner than those described there has evidently been an error in connecting. The connections should be traced out again, by means of Fig. 10. Note that the two deltas are opposite in their connections, and that this opposition is necessary for a double-delta circuit.

SELF-STARTING MOTORS AND ROTARY CONVERTERS

Self-starting machines require a different method of treatment from the preceding, because the sequence of phases of the incoming machine must be made the same as that of the running machine before the incoming machine is running in synchronism.

Two-Phase—Determine which leads belong to the same phase, connect to the machine, and close the switch. If the machine starts in the wrong direction interchange the leads of one phase (or interchange phases in case of two-phase—three-wire circuits).

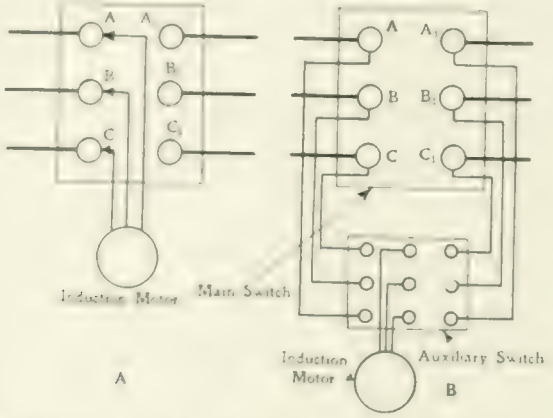
Three-Phase—Connect the leads to the machine, and close the switch. If the machine starts in the wrong direction interchange any two leads.

Six-Phase—Double-Delta—Connect only one delta at a time, the same as for three-phase. See that the machine rotates in the right direction, whichever delta is connected. If each phase rotates the machine in the wrong direction, the reversal may be made on the three-phase (high-tension) side of the power transformers.

Six-Phase Diametrical—Connect as in Fig. 9, omitting the lamps, and leaving the switch open. Measure the voltage between switch terminals *1* and *3*, *3* and 5, and 5 and *1*. The voltages should be 1.73 times the diametrical voltage. If two of the voltages are too low, interchange the leads to the transformer to which the two voltages are low. These three voltages should then be equal. If the machine starts in the wrong direction, interchange those leads at the rotary converter which connect to *1* and *3* and those which connect to *4* and *6*. Or if preferred, interchange any two of the three-phase (high-tension) leads.

INDICATING AND PROTECTING DEVICES

Instead of lamps, an induction motor may be used to indicate reversal of phases. It is connected as in Fig. 13*a* or *b*. The motor leads are connected first to the main switch terminals *A*, *B*, *C*, and then in the same order to *A*1, *B*1, *C*1. Care should be observed not to cross the leads in changing the connections, as this reverses the indication. If the motor rotates in the same direction in each case, the main connections to the switch are correct. If the motor reverses, any two main leads on one side of the switch may be interchanged. The arrangement of Fig 13*b* is convenient where per-



FIGS. 13 (a) AND (b) — INDUCTION MOTOR CONNECTIONS FOR CHECKING ROTATION OF PHASES AND INDICATING REVERSAL ON A THREE-PHASE CIRCUIT

manent connections are to be maintained, to show whether the sequence of phases has been reversed. Usually, however, in such cases the reversal is likely to take place on only one side, so that a single throw auxiliary switch is sufficient.

It is sometimes important to provide an automatic signal, or to open a circuit breaker instantly, in case of reversal of phases. In such cases a relay can be provided, having a moving element that tends to rotate against a stop when the sequence of phases is normal; but if the sequence is reversed, the direction of rotational tendency of the relay is reversed, and a contact is closed, lighting a signal lamp or tripping the circuit breaker.

THE JOURNAL QUESTION BOX

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Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

737—Induction Between Circuits Crossing at Right Angles—If a 110 volt lamp circuit crosses a 2 200 volt single-phase feeder circuit will increase or decrease of distance between the circuits have any marked affect on the inductance effects and what would be the difference, assuming of course that the respective circuits are properly insulated from each other? J.E.I.

With the circuits arranged at right angles there would be no induction between the two, no matter how small the distance separating them. In order to have mutual induction between two circuits they must be more or less parallel to each other. The induction is then greater the nearer the circuits and the greater the length of line through which they parallel each other. E.R.S.

738—Connection of Ammeter Shunts in Parallel—In connection with a direct-current generator capable of giving 10 000 amperes at a pressure of about five volts it is desired to use an ammeter to indicate currents up to 8 000 amperes. We have two 4 000 ampere ammeters with shunts. Could sufficiently accurate measurements be obtained by inserting the two shunts, connected in parallel, in one side of the circuit and connecting the leads of one ammeter to both shunts, assuming that the shunts are not quite identical, or could both ammeters be used simultaneously? J.E.I.

One meter connected to the two shunts would not give reliable readings even if both shunts were adjusted to give the same drop at normal load. The difference in resistance of the connections would be practically certain to cause unequal division of current between the two shunts. The section of ammeter lead between shunts might be subject to a heavy current tending to equalize the drop. If the two ammeters are connected each to its own shunt with shunts in multiple the sum of the ammeter readings will give the total current in the circuit. H.B.T.

739—Motor Efficiency in Relation to Power-Factor Calculations—The company which furnished a 50 hp, 440 volt, 62 amp. per terminal, three-phase motor guaranteed 89 percent efficiency and 88 percent power-factor at full load. A test was run using a three-phase portable wattmeter, voltmeter, ammeter and a portable power-factor meter. The following average results were obtained:—41.6 kw, 456.5 volts; 60.8 amps. and 85.6 percent power-factor with power-factor meter. The following points remain to be cleared up: *a*—41.6 kw equals 55.7 hp. Is this motor carrying 5.7 hp overload, or, figuring the efficiency as 89 percent, is there only 0.5 hp overload? *b*—In determining the power-factor to check the guarantees, is the above value of 85.6 percent power-factor to be taken at 50.5 hp or at 55.7 hp? *c*—Power-factor is expressed by the ratio

$$\frac{\text{Kw Input}}{\text{K.v.a. Input}}$$

What does this mean with respect to the guarantees; or in other words, does the efficiency have to be figured, in order to compare the power-factor as obtained with the power-factor guaranteed. F.H.W.

a—The rating on the name plate designates the output of the motor, at what is considered as

full load. The 41.0 kw read by the instrument denotes the input to the motor, and not the output. Assuming that the motor is carrying full load approximately, viz. 50 hp. and that the efficiency at full load is 81 percent, then the output as shown by the reading equals 41000 × 746 × 81 = 40.5 hp, which is as near to full load as would probably be attained by instrument readings. From this it will be seen that the motor is not carrying an overload. 4—The above 85.6 percent as read by the power-factor meter is the power-factor corresponding to the output load of 40.5 hp, because the guaranteed power-factor is for the full-load output, viz., 50 hp, by which it is to be checked. 5—In the present case

$$\text{K.v.a. Input} = \frac{\text{Kw Input}}{456.5 \times \sqrt{3} \times 60.8} = \frac{41000}{}$$

85.5 percent. If these readings are correct, then the power-factor reading by instrument (85.6) is too low; however since this error is within one percent, it is quite allowable, for this kind of a reading. Also the voltage reading (456.5), shows that the motor is being operated at about four percent above normal voltage, which means that the magnetic densities and magnetizing current are higher than normal. It is evident that the efficiency does not have to be figured in order to find the correct power factor for a certain load, if the above formulas are used. However in order to get the above readings for an absolutely correct output load, it would of course be necessary to know the efficiency, in order to determine this load by electrical measurements. C.L.S.

740—Secondary Current and Voltage in Wound Secondary Motor—How can I find the current and voltage in the secondary winding of a wound rotor, variable speed, three-phase induction motor, at the different steps from "resistance all in" to "resistance all out." Is there any formula for determining these values? T.C.M.

The method of calculation based on the operation of the motor as a transformer by applying suitable voltage to the stator with the rotor locked, is given in No. 374, July 1911. Calculations are based on the assumption that the secondary current per phase is directly proportional to the torque delivered. The answer referred to also suggests a method of obtaining secondary voltage at standstill. At synchronous speed, the secondary voltage would be zero, since the secondary conductors are moving at the same speed as the revolving field set up by the primary, and no cutting of flux occurs. The secondary voltage at any other speed may be determined by means of the following formula: $B = 100 - \frac{R \times 100}{S}$; where $S =$ synchronous speed of motor, $R =$ any speed between zero and synchronous speed and $B =$ percent secondary voltage at speed R in terms of secondary voltage at standstill. M.W.B.

741—Direct-Current vs. Single-Phase Motors for Small Printing Presses—A printing press requires a 0.3 hp direct-current motor for operation; would a single-phase motor of the same size be satisfactory, especially for starting, so far as available torque, relative economy in current consumption, etc., are concerned. E.S.V.D.

Printing presses ordinarily require greater starting torque than that available from a motor which would be fully loaded when running the press, especially if the press is equipped with fly-wheel. A direct-current series or compound motor would of course give relatively large starting torque and would therefore be particularly suitable for the operation of such machines. If a single-phase motor were used it should preferably be of either the repulsion type or one arranged for starting as a repulsion motor, certain makes of which are available in sizes as small as 0.3 hp. The current consumption and efficiency would correspond favorably with those of the direct-current motor. L.B.B. and A.M.D.

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The Universal Central Power Station

The advantages of a single central station power system for supplying electric power for general city service and for electrified railways were presented at a recent meeting of the American Institute of Electrical Engineers, by Mr. Samuel Insul. In practice, as well as in theory, he is one of the foremost advocates of the large power system. As head of the Commonwealth Edison Company he has made Chicago notable the world over for the size of its central station system and its high load factor of over forty percent. This company is now supplying power in large amounts for street railway operation. It is well to give serious attention, therefore, when such a man speaks emphatically concerning the policies on which he is an authority.

As a prime object of the central station manager is to increase the all-day or aggregate output as much as possible and to increase the maximum or peak load as little as possible, he welcomes long-hour loads without peaks, or even with peaks if they occur at acceptable times. It is the diversity factor, the fact that peaks are not simultaneous, so that the aggregate peak of two kinds of load is not equal to the sum of their individual peaks, that is emphasized by Mr. Insul as the great reason for the more economical generation of power in a large single station or system. He showed daily load curves of different requirements. One might presume that such diversified interests as ordinary electric light and power supply, street railways, subways and steam railroads would show a very favorable diversity factor. Daily load curves for various requirements of New York City were exhibited. These included the New York Edison Company, the surface railways, the elevated and subway systems, the Pennsylvania Terminal, the New York Central and the New Haven Railroads. The curves were all substantially alike, each had a minor peak in the early morning, a fair load during the day and a maximum peak in the late afternoon. The curves were so nearly of the same shape that careful labeling was neces-

sary to distinguish them. The diversity factor of these various demands was considerably under ten percent, but even then the possible saving in power house investment mounted to very large figures. The saving in transmission cables, and in sub-stations also, may be very considerable, as their diversity factor is greater than that of the power station.

Mr. Insul referred to a conversation regarding electrification with the president of one of the large steam railways terminating in Chicago, who spoke several times of the great amount of power required for operating heavy trains. He was quite astonished when told that the power requirements of his terminal could be assumed by the central station of Chicago with scarcely an appreciable addition to its load. In the New York presentation Mr. Insul pointed to the curve showing the power used by the New Haven road, and said it was too small to consider in a big scheme—apparently without intending this as a compliment to the efficiency with which this important road uses its power.

Diversity factor is not the whole justification of the large central station. Concentration of administration and engineering ability in power production is an important factor. The making of power has become a business in itself. Electric operation has made large power production possible. This has not always been so, for arc lamps, incandescent lamps and street cars each used to have its own particular type of generator, nor could the generators be located very far from the work they were to do. But now all kinds of service—street and residence lighting, electric fans and big factories, street cars and express trains—can be operated from the same bus-bars. The polyphase alternating-current power transmission at higher voltages and the large turbo-generator units make it practicable to produce the power which is to serve a city and its surrounding territory by one power system instead of a hundred or a thousand small independent power plants. The theoretical possibility of doing this is generally recognized, but its economic advantages and practicability have not yet been fully realized. In New York City, for example, a half dozen or more companies erected their own power plants for generating 25-cycle current. Mr. Insul says that millions could have been saved by combination. This is coming to some extent, as the elevated, the subway and some of the surface car lines are now served from common power houses.

Street railways are finding that they can buy power cheaper than they can make it. The example furnished by Chicago has been followed by Cleveland, where a careful analysis, conducted jointly by those interested and an outside expert, showed that the proposal of the illuminating company was less than it would cost the railway to make its own power, and it also enabled the railway interests to use their limited capital for needed equipment. The consolidation of small central stations with large power companies for serving smaller cities and towns in the same county or district may not be so impressive in magnitude, but is scarcely less attractive as to the economies which may be secured.

The advantages of diversity factor and economic production on a large scale can accomplish much, but there is still a possibility which is not utilized. The load-factor for the service above considered is still considerably below fifty percent. That is to say, the station output in kilowatt-hours could be doubled without increasing the size of the power house if the power could be used during the off-peak periods in the middle of the day and the latter part of the night. The published rates in one large city give the price of power for 100 percent load factor (24 hours uniform load) at about half of that for power having 25 percent load factor (equivalent to six hours' full load).

To make cheap power it is necessary to produce all the power in one system and to increase the load factor. Naturally cheaper power makes new applications practicable. Twenty years ago electric generators were driven by engines of a few hundred horse-power, ten years ago by engines of a few thousand horse-power, now by turbines of a few times ten thousand horse-power, and the cost of producing power has been greatly reduced. All this means that the manufacture of power is now on a new basis.

CHAS. F. SCOTT

The Field of the Industrial Motor Application Engineer

It is the field of those who are engaged in applying industrial motors to demonstrate to the prospective users of motors that, if properly applied, increased returns will result from the use of electric drive. Ordinarily this must be accomplished as the result of a rigid investigation of the manufacturing operations, type and location of machinery, amount of power needed, speed requirements, etc., as well as the character of the labor employed. In other words, an industrial engineer, in

addition to having a thorough knowledge of manufacturing operations, and of motor and engine characteristics, must also be an efficiency engineer. Data upon which conclusions may be based are obtained by observations and tests, and by analysis and comparison of the various fundamental physical and mechanical components involved. The principal items to be analyzed in ordinary industrial operations are:

1—The routing system, involving the location of the machines, and the moving of materials to and from the machines with overhead cranes, industrial railways, trucks, jib cranes, other mechanical drives, or by hand.

2—The handling of the materials at the machine, including placing the work or removing the work from the machine with main crane, jib crane, or other mechanical means, or by hand; and performing the work, which involves the securing of the proper speed characteristics of the machine, proper facilities for adjusting the various parts of the machine, and proper records of the time and power required for the various operations.

3—The lighting, ventilation, heating and sanitary conditions.

With all of these conditions correct, not only is production facilitated, but the moral effect upon the employes is to impel them to do everything just right, and the result is high quality as well as maximum efficiency. Power is required both for moving the materials being manufactured and for working upon these materials. Proper methods of applying power, therefore, form an important factor in securing economy in shop operation. These methods are more important than economy in power consumption, because maximum production depends upon the correct application of power, whereas the cost of power itself is comparatively small, usually only a few percent of the shop operating expenses.

It is evident that all the units in a shop should be independently driven in order to fulfill all of the conditions outlined above. An efficient shop cannot be handicapped by line shafts which limit the arrangement and location of machines. For these reasons, individual motor drive forms a big item in the solution of the majority of the problems of efficiency engineering in shops and factories. With this method, the most economical routing system can be installed since the machines can readily be located where most effective. Cranes and other handling devices can thus be operated without danger or interference. As each machine is an independ-

ent unit, its speed can be varied to best suit the work at hand, quickly, and without overhead complications. It is also possible to obtain graphic records which will show all operations and delays, when work is being done or is removed from a machine, etc. By eliminating line shafts, daylight coming from skylights will not be reduced and artificial illumination can be laid out for maximum efficiency.

In going after this class of business, the industrial engineer, whether acting on a consulting basis, or representing a central station or apparatus manufacturer, must first interest the factory manager. To do this a good impression must be made at the start. The details of the prospective customer's business must be understood and originality of ideas must be shown. Factory managers are always interested in new ideas, and originality is the strongest force with which to attract attention and arouse interest. An individual who has not originality and an attractive personality had better choose a different field. Some engineers copy ideas which have obtained success for others—they are following a leader, helping him to standardize his ideas, but will never be leaders themselves. Instead of copying, they should originate something better. This practice promotes progress and progress is the object of efficiency engineering.

While visiting a factory the engineer should be on the watch for any inefficiencies that may exist and point them out to the manager at once. Originality, based on sound engineering knowledge and experience, combined with proper analysis, will suggest how to overcome the source of deficient economy. After several minor suggestions are made the manager will decide whether or not he wishes the engineer's services. His decision will depend upon the impression created, and this will depend upon the originality and the soundness of the logic employed in the preliminary minor analyses. After a favorable decision has been made, the industrial engineer should employ all his knowledge of fundamental mechanical and physical principles, and apply the results of his previous experience to his best ability. Success will depend upon the satisfaction he produces, and giving satisfaction will increase his self-confidence and accordingly his chances of obtaining favorable action in future cases.

Tact and diplomacy are necessary in asking questions and obtaining the desired information. The manager should not be

given the impression that he does not know his own business. In the shop, the operators must not be antagonized. Much valuable information can be obtained from them, as they are in a position to know the details which produce efficiency. The engineer must, therefore, be of a flexible disposition; he should be able to handle both "capital" and "labor." He must not be afraid to put on overalls and get his hands dirty in the shop, and at the same time he must have the necessary refinement to deal with the officials of an establishment. Knowing from his previous experience that his method of analysis is correct, he must not be disheartened if others do not agree with him at first. It takes time to overcome any prejudices that may exist and to make clear the possibilities of improvement by the use of analytical methods with which they may not be acquainted.

Skill in this profession, as in all others, is obtained by constant practice. A technical graduate should not enter this field immediately upon leaving college. A thorough understanding should first be gained of the operating characteristics of electrical power apparatus. After a technical course of instruction, this can be obtained by designing, constructing, or operating the apparatus, observing methods used in shops of various kinds and analyzing the conditions observed. This experience may be secured at the plants of electrical manufacturers, with public service companies which are actively increasing their motor load, or at industrial plants using electric drive. The amount of experience the individual gets depends largely upon his own originality and energy in endeavoring to have his ideas carried out by referring them to his superior.

A. G. Popcke

Building up Power Districts

It has been the prediction of those who have closely followed the development of the electric art that the future will see great districts or states supplied with power from a few immense central generating plants whose high tension transmission lines will extend for great distances, and whose sub-stations will supply the communities now served by many independent stations. That part of the United States known as the Pacific Slope—the territory West of the Rocky Mountains—possibly affords the best present day realization of this idea, and it is particularly exemplified in the state of California. A study of the conditions in that

state, therefore, will greatly assist in determining whether or not we may expect similar developments in other parts of the country.

A long distance transmission line in some respects resembles a railroad in its relation to the territory through which it runs. The first concern in the planning of a new railroad is the possibility of securing freight business in sufficient quantity, and especially local business with short hauls. A long stretch of track between two points, with no intermediate shipping points, must be regarded exactly like a bridge, the investment is high and the proportionate returns are low. This naturally means small returns per mile of track as compared with a road running through a more productive section. Unless the line connects two important shipping points the earning capacity of the road per mile will be low and the advisability of building it questionable. In general, the initial cost per mile of track is the same whether a road traverses a productive or non-productive territory.

So it is with the building of a transmission system. Unless the cost of generating power is much lower at one point than at another it will not pay to run a transmission line any considerable distance between the two points unless business can be secured along the line which will help bear the total expense. Thus, the realization of the dream of great generating plants can only come when the possibilities for the utilization of electric power in rural as well as urban districts are developed.

California is covered with a network of high tension transmission lines, mostly those of hydro-electric plants which find the source of their power in mountain streams and which must run lines of great length to reach the larger centers of population. But along these lines are sub-stations serving mines, lumber districts and particularly agricultural communities where electric power is used to operate pumps for irrigation as well as to drive machinery for other farm purposes. The wonderful productiveness of California soil for raising fruit, nuts, olives, etc., is a result of the free use of water; especially is this true in Southern California, where for practically eleven months in the year the country is bathed in warm sunshine and rain is unknown. Here irrigation is a necessity, and here we find millions of dollars invested in generating plants and transmission lines to serve an almost purely agricultural community. Although oil is plentiful and it might be expected that gas engines would predominate, the electric motor is most popular as a power agent. Here the centralization of power generation is

profitable, and in fact almost necessary, but this fact must be borne in mind, it is the local business—the short hauls as it were—which make the great electrical developments in California practicable. Until the application of electrical energy to rural power requirements is developed to a greater extent than at present in the Middle West and East, we cannot reasonably expect that long distance transmission lines will be economical or necessary, with the few exceptions of great power developments like those at Niagara Falls, where extremely low generating costs offset the high expense of building long transmission lines.

It cannot be denied that the wonderful growth of California industrially and agriculturally, is in a large part due to the courage and foresight of those men who have invested millions in the development of great electrical generating stations and who have educated the people to the use of electric power in industries which in the East have always been more or less dedicated to steam or gas engine plants. Those men did not find the market for power ready made. They have built up the state and encouraged the influx of farmers, as well as the development of the mining industry, by providing power at a reasonable cost and pointing out the possibilities for its use. It has been a campaign of education there as everywhere.

The future of the large central generating station is dependent on broadening the scope of its work and applying its energy to still greater fields. That is what California has done and what is being done in Washington, Oregon, Idaho and other western states where the central stations are a very important factor in the industrial development of the state. But as already indicated, these important developments are being accomplished by taking advantage of opportunities for business not only in the large centers of population but in the rural districts as well. D. S. Brown

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Illuminating Engineering and the Central Station

It has seemed somewhat as if the major attention of central station men has been directed, in the immediate past, to the consideration of off-peak power loads. No one will gainsay the importance of this consideration. Other important items are, however, beginning to assert themselves in the economic relations between profits and the satisfied customer.

The matter of explaining to a customer how his residence should be equipped with electric lamps and reflectors in order to obtain the

most satisfactory results is practically as important as the reading of his meter. In fact, a customer who feels that the method of obtaining the best and most economical illumination results in his home has been explained to him in an intelligent manner is apt to be kindly disposed toward the central station, and such a feeling of satisfaction is invaluable to the company.

Lighting installations, regardless of location, include three important items—the design, the application and the upkeep or maintenance. No design is satisfactory, no matter how well the illumination requirements are met, unless first cost and maintenance charges are consistent with the results actually obtained. A few practical hints on the installation of factory lighting systems are presented in the present issue of the JOURNAL which are drawn from the wide experience of the author in this kind of work. One of the most valuable features of the article by Mr. Clewell lies in the suggestion that it is frequently possible by making certain changes in the illumination design, to simplify and cheapen the wiring cost without detracting from the excellence or permanence of the installation. On the other hand, it does not pay to sacrifice illumination features to any great extent in order to decrease cost of installation, as in the majority of cases the entire cost of installation is only a small percent of the saving in time and superior workmanship which is secured by the improved lighting. The principles contained in this article are such as to adapt it in a general way to all classes of illumination. The attention of central station men in particular is directed to the value of bringing material of this nature before their customers in order to improve local conditions and thereby increase their satisfaction with the power company's service.

The recent introduction of the long hour flame carbon arc lamp makes the article by Mr. Stephens particularly opportune at this time. The author sets forth the various steps leading up to the development of the long hour, flame carbon arc lamp, and explains the new and unusual features associated with the operation of this type of lamp. While flaming arc lamps have been used abroad successfully for a number of years, their commercial introduction on a large scale in this country has been delayed by the prohibitive cost of operation due to frequent trimming, a factor which is of considerably more importance in this country than abroad, on account of the difference in labor costs. The long burning lamp has overcome this objection, and there appears to be a large field for its use, especially for industrial plants and street lighting.

Another article of interest is that by Messrs. Hurley and Padon in which a typical installation of metallic flame arc lamps in an average Western town is described. This article contains considerable information connected with the principles of street lighting, and also sets forth at some length the items of interest associated with the station equipment and the advantages to be derived by the operation of direct-current series arc lamps by means of mercury rectifier outfits.

It is to be hoped that the interest manifested the past year or two in practical illumination will continue to grow. To be productive such work should be given systematic attention in an endeavor, not only to improve present conditions, but to raise the standard of illumination facilities in the homes of the community, as well as in the industries, streets, park areas and suburban roadways. Cooperation between the manufacturer and the central station has done much during the past year to promote the realization of these results. A continued helpful relation of this kind, through the distribution, by the manufacturers, of scientific and accurate data on lamps and lighting equipment and their proper application to specific purposes, coupled with a direct interest by the central station men in the use of the most effective illumination will undoubtedly do much toward securing marked improvements in the entire lighting situation.

T. J. Pace

THE INSTALLATION OF INDUSTRIAL LIGHTING SYSTEMS

C. E. CLEWELL

THE design of industrial lighting systems takes into account primarily the location of lamps for the production of a definite result. In planning such systems the wiring and installation problems are apt to be overlooked in favor of the advantages of certain lamp locations from the standpoint of the illumination effect. While the lamp locations should be determined for the production of excellence in the illumination effect, it should be remembered that a slight change in such locations may sometimes reduce the cost of wiring very materially with only a slight modification in the resulting illumination. Attention should, therefore, be directed to the importance, first, of scientifically distributing the outlets, and second, of minor changes which may be made to accommodate wiring conditions, which, however, should always take a secondary place.

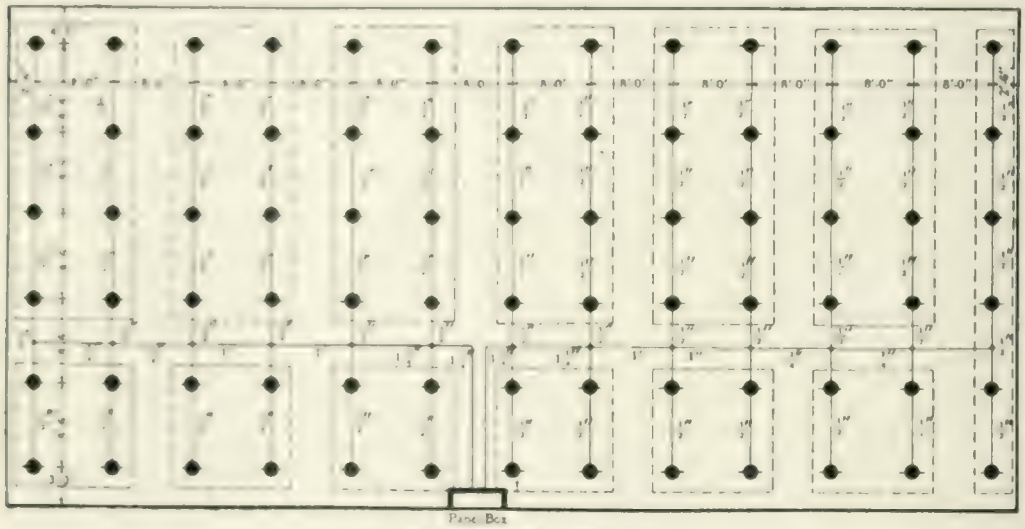
THE ILLUMINATION DESIGN

In former days a request for lighting in the shop was very generally met by hanging a few lamps here or there without regard to uniformity or advantageous intensities of the illumination. Today the illuminating engineer investigates the locations for which lighting is required and after measuring the floor space and ceiling height, and noting the surrounding conditions, calculates the number of lamps necessary properly to light the location; chooses a size of lamp and type of reflector which is best adapted to the given conditions; mounts the lamps at such a height as to prevent glare; controls the lamps in groups which will give the system a flexibility through turning off certain lamps when not required; and in general takes into account those principles and items which differentiate the old haphazard lighting from modern systems carefully and scientifically planned.

The illumination design, to be of service to the wiremen, should contain in a clearly defined manner all the items of information necessary to enable them to install the lamps according to the plans and, furthermore, should contain a list of the various materials which are required for the installation. A design drawing is shown in Fig. 1, which not only shows the lamp locations, but indicates the wiring system, the location of the conduit and fittings, the location of the panel boxes, and also, by dotted lines, those lamps which are to be controlled from one switch. In the lower portion of this

drawing is found a complete list of materials required for the installation. This list greatly aids the one who is responsible for the ordering of the necessary supplies.

The Estimate—Upon the completion of the drawing it is always desirable to obtain an estimate of the expense associated with the installation of the system. This is comparatively simple if the design drawing contains all the information indicated in the previous paragraphs. In those cases, however, where the drawing does not show



BILL OF MATERIAL

Item	Material	Item	Material
1	1—15-Circuit Panel Box	13	2—$1\frac{1}{4}$" Conduit Elbows
2	78—100-Watt Tungsten Lamps	14	2—$1\frac{1}{4}$"x$1\frac{1}{4}$"x$\frac{1}{2}$"x$\frac{1}{2}$" Cond. Crosses
3	78—100-Watt Reflectors	15	2—$1\frac{1}{4}$"x1"x$\frac{1}{2}$"x$\frac{1}{2}$" " "
4	78—Reflector Holders	16	2 - 1"x1"x$\frac{1}{2}$"x$\frac{1}{2}$" " "
5	78—Keyless sockets	17	2—1"x$\frac{3}{4}$"x$\frac{1}{2}$"x$\frac{1}{2}$" " "
6	78—Wood Bushings	18	2—$\frac{3}{4}$"x$\frac{3}{4}$"x$\frac{1}{2}$"x$\frac{1}{2}$" " "
7	54—Ft. $1\frac{1}{4}$" Iron Conduit	19	1—$\frac{3}{4}$"x$\frac{3}{4}$"x$\frac{1}{2}$"x$\frac{1}{2}$" " "
8	62—Ft. 1" Iron Conduit	20	1—$\frac{3}{4}$"x$\frac{1}{2}$"x$\frac{1}{2}$" " Tees
9	52—Ft. $\frac{3}{4}$" Iron Conduit	21	1—$\frac{1}{2}$"x$\frac{1}{2}$"x$\frac{1}{2}$" " "
10	567—Ft. $\frac{1}{2}$" Iron Conduit	22	26—Dead End Conduit Fittings
11	2724—Ft. No. 14 R. C. Wire	23	500—Ft. No. 16 Flexible Cord
12	15—Panel Switches	24	52—Straight Through Cond. Fittings

FIG. 1—TYPICAL ELEVATION PLAN, SHOWING WIRING AND LIST OF MATERIAL

the wiring arrangement but simply indicates the location of lamps, it is necessary for the wiremen to pencil in all circuits, to measure up the amount of wire, and to tabulate all the other material required for the work. Fig. 2 indicates in a general manner the form of estimate which will be found most advantageous in connection with industrial lighting work. It is convenient and helpful in summarizing such an estimate to divide the total amount by the number of lamps in order to determine the cost of installation per lamp. The cost per lamp when compared with costs in other similar loca-

tions, will serve to indicate whether or not the installation cost is excessive.

Another valuable feature of the preliminary estimate lies in the opportunity it frequently gives the designer to revise the location of lamps slightly so as to reduce the cost of installation without materially affecting the resulting uniformity of the illumination. One of the most helpful features in this connection is the inspection of the location by the designing engineer in person in order to ascertain whether the surroundings present any characteristics of an exceptional nature which in themselves are apt to produce difficulties in the arrangement of wires. A sketch of a typical shop bay with a

Amount	Material	Style	Price
	Lamps		
	Reflectors		
	Reflector Holders		
	Wire		
	Lamp Cord		
	Conduit		
	Conduit Bends		
	Crosses		
	Tees		
	Lock Nuts		
	Conduit Bushing		
	Sockets		
	K.W. Cutouts		
	Wood Bushings		
	Fuse Blocks		
	Fuse Plugs		
	Fuses		
	Switches		
	Switch Boxes		
	Screw Hooks		
	Sash Chain		
	Brads		
	Wood Screws		
	Tape		
	Solder		
		Total Material	
	Wiremen's Labor		
	Overhead Expense		
		Total,	

FIG. 2—TYPICAL ESTIMATE FOR A LIGHTING INSTALLATION

preliminary layout is shown in Fig. 3, while Fig. 4 indicates the same shop space in which the lighting arrangement has been slightly modified to meet special conditions. The comparison of these two figures shows that the arrangement of lamps is practically as symmetrical in one as in the other; but the cost for the installation of the second system is very much lower than the first. Attention to items of this nature will often be rewarded by large economies in the installation cost.

Checking the Work with the Drawing—After a lighting plan has been drawn up with the greatest care it will almost invariably be found that the interpretation of this drawing by the wiremen results in the location of some lamps slightly at variance with the

drawing. This is due primarily to inaccuracies in the measurement of the location; that is to say, the width and length of the space to be lighted. If, for example, a series of columns across a given space divides the space into a number of bays, and furthermore, if the measurement by the wiremen is begun at one side of the building, an error in the measurement made in one or another of the bays may result in considerable confusion if the attempt is thus made to lay out the locations on the ceiling in accordance with spacing distances which have been indicated on the drawing from an unchecked overall dimension. For these reasons it is a distinct advantage for the one who plans the system to check up the drawings while the installation is being made. A suggestion to the wiremen here and there if made in time may save tearing out the entire sys-



FIG. 3—PRELIMINARY ILLUMINATION PLAN IN A SHOP SECTION, SHOWING AN UNSATISFACTORY CONTROL ARRANGEMENT, DOTTED LINES INCLUDE ALL LAMPS CONTROLLED FROM A SINGLE SWITCH

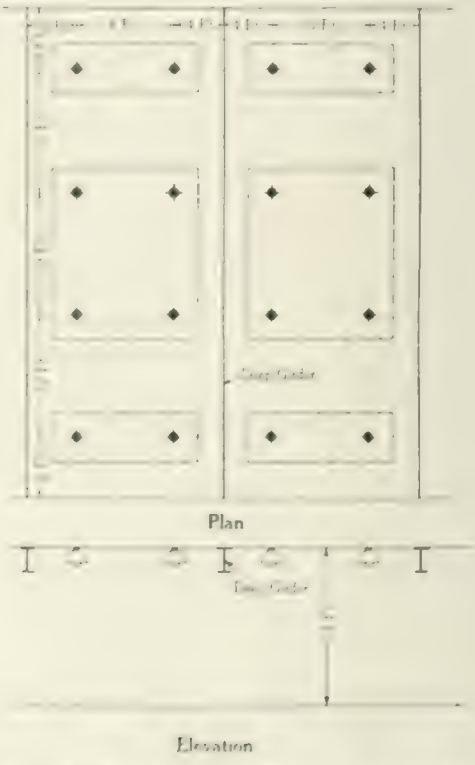


FIG. 4—REVISED CONTROL ARRANGEMENT FOR THE SHOP SECTION SHOWN IN FIG. 3. THE CONTROL CIRCUITS DO NOT EXTEND BEYOND THE BAY IN EACH CASE, RESULTING IN LESS COST FOR INSTALLATION AND OPERATION

tem of wiring on account of some gross error which has crept in due to a misunderstanding of the drawing.

Two items should, therefore, be kept in prominence before the mind, first, the drawing up of plans as accurately and simply as possible, so as to reduce the possibilities of misunderstandings by the

wiremen, and, second, after all the care possible has been exercised, to check up with the drawing from time to time while the wiremen are at work.

CEILING CONSTRUCTION*

The classes of ceilings found in the various industrial plants cover a large variety of materials and kinds. There are to be found, for example, ceilings of wood, brick, tile, metal and cement, as well as those locations in which there are no ceilings at all but where the overhead construction consists solely of girders, these being the only means of support for lamps and wires other than the roof itself.



FIG. 5—PHOTOGRAPH OF SHOP SECTION SHOWING DEEP GIRDERS IN THEIR RELATION TO THE WIRING FOR LAMPS

In addition to the varying materials, there is also to be found a large variety of girder arrangements. In many cases the girders extend to a considerable depth below the ceiling surface, breaking up the ceiling into sections or bays. This limits the wiring arrangement to an appreciable extent on account of the difficulty of carrying wires under girders. A wiring system planned in a symmetrical manner with respect to the bays, is found in the location represented by Fig. 5, the circuits being so arranged that no wires have

*For additional information on this subject see article entitled "Shop Lighting Installation" by the author in the *American Machinist*, October 26, 1911.

to cross the girders, while the main feeders are run on the under side of the girders. If it had been thought advisable to control three rows instead of two by one switch, it would have necessitated either drilling through the girder in order to connect the lamps in the adjoining bay to the lamps in the first bay, or these same wires would necessarily have been run underneath the girders, which is not only a difficult task, but usually expensive and unsatisfactory.

Wood ceilings present the easiest class of locations as far as wiring is concerned and in such cases the wires may either be strung on knobs or cleats in the form of open work, or may be concealed in wood or metal moulding. Where no ceilings exist and the wires must be supported on the under side of girders, it is found advisable when the number of lamps for a given floor area is large, to install stringer boards underneath the girders to which the wires may be attached by means of wood or metallic moulding. In office locations where tile or metal ceilings are found and where it is practically impossible to conceal the wiring, due perhaps to the fact that the installation is to be made in an old office where lighting has been found to be inadequate and a new system is desired, metallic moulding has been employed in many cases with satisfaction, both in the work of installation and in the appearance when completed.

The ceiling not only presents difficulties in a great many cases to the wiremen, but thus increases the cost of this work. One is apt to think at times that the additional expense for a large number of outlets compared with what would be required if one-half or one-fourth of the number of lamps were installed, is not warranted. Careful calculations, however, indicate that in practically all industrial work the additional expense for a sufficient number of lamps, in order to provide satisfactory illumination at any point on the floor space, is very small in comparison with the direct economies resulting through reduced labor costs and better workmanship made possible by the more efficient system of lighting. In general, therefore, the number of outlets should be determined primarily on a basis of the actual lighting results, the cost of installation being reduced only when such a modification is not made at the expense of a good illumination effect.

METHODS OF SWITCH CONTROL

In those cases where the wiring is made a part of the building before its completion, the wires are usually located between floors and ceilings, thus enabling the control circuits to be run to switches placed at convenient points on walls or columns. In this way lamps

may be controlled from a single point over a considerable area and the appearance of the wiring and control arrangement does not enter into the case. In most industrial lighting work, however, no such refinements are feasible. Where wood moulding or conduit is used the switch control circuits are very often placed on structural steel columns or brick walls, as the case may be, the expense of such circuits being dependent to a great extent on the ease with which the moulding or conduit may be attached to the column or wall, and also to some extent on the distance from the lamps to be controlled.

In recent years the so-called pendant switch, which is attached directly to the lamp circuit by means of a piece of flexible cord, has become popular. There is, however, a slight objection to the location of a switch in a pendant position, especially under shop conditions, due to the tendency of the employees to tamper with the mechanism of such switches, and also due to the fact that they may be accidentally broken. Another type of switch which has lately become quite useful in industrial work is the so-called pull switch, which has the advantageous characteristics of the pendant switch in that it may be connected directly to the circuit, thus obviating the use of long control circuits. It differs from the pendant switch, however, in that the switch itself is located at the ceiling and the control is effected by means of a cord to the end of which is attached a small handle. This makes it impossible for the switch to be tampered with as in the case of the pendant switch, and its use has resulted in lower cost both for installation and operation.

As will be apparent from a slight consideration of the various factors, it is an advantage to control lamps in rows or groups parallel to windows. In the older installations where a single row of large lamps was used down the center of the aisle such precautions were not necessary. In modern lighting installations, however, where a larger number of smaller lamps is used, it becomes highly expedient to give special attention to the control circuits. For example, Figs. 6, (a) and (b) show a low factory space with windows at either side of the building where a large number of lamps of medium size have been used. In this location the original illumination design called for six lamps to be controlled from one switch as indicated by the dotted lines in part (a). After a time, however, it was found that in those sections of the shop where a large number of workmen were employed in close proximity to each other, very often the lamps towards the center of the shop were needed while those men located near the windows were still provided with suffi-

cient natural light. A modification of the original wiring arrangement was, therefore, necessary as shown in part (b) of Fig. 6, giving considerably more flexibility to the system and also affording economy in the use of lamps by permitting only those lamps which are needed at any one time to be turned on.

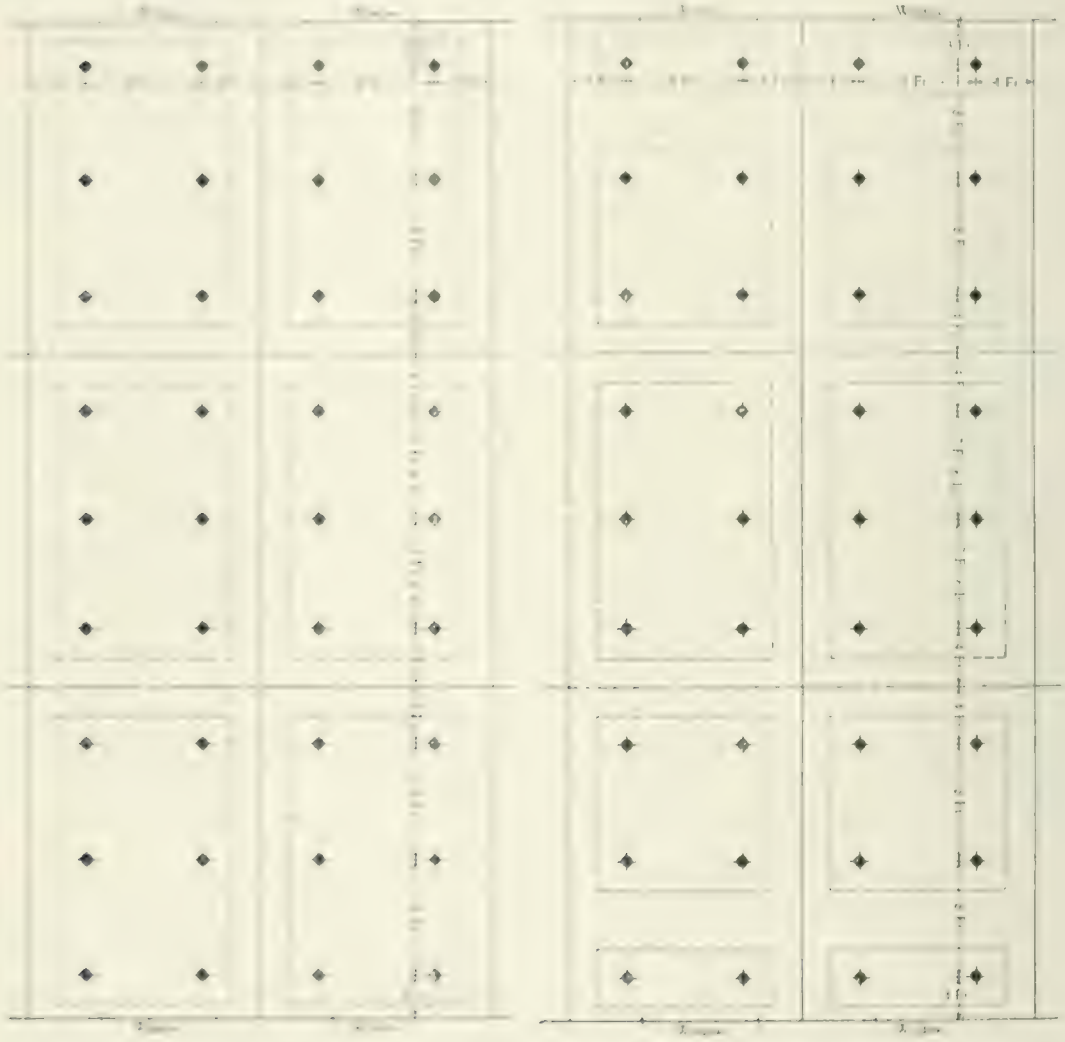


FIG. 6 (a)—PLAN OF FACTORY SHOWING LOCATION OF WIRING AND LAMPS ON PARALLEL PANELS WITH DIRECT THROUGH, ALTHOUGH APPARENTLY IN A VERY REGULAR AND SYSTEMATIC MANNER

FIG. 6 (b)—PLAN OF THE SAME FACTORY SHOWN IN FIG. 6 (a), WITH MODIFIED CONTROL ARRANGEMENT, PERMITTING LAMPS NEAR WINDOWS TO BE TURNED OFF WHEN THOSE AT CENTER OF BUILDING ARE STILL REQUIRED

MAINTENANCE*

The problems of maintenance are primarily dependent upon the physical characteristics of the lamp to be used. The method of installing lamps has, however, quite an effect on the maintenance

*See also "Notes on the Operation and Maintenance of Factory Lighting Systems," in the JOURNAL for December, 1911, p. 1082.

expense through the ability afforded to wiremen and lamp trimmers to get at the lamps for repairs and upkeep without any very considerable difficulty. This problem is of particular importance where the ceiling height exceeds from 14 to 16 feet. Lamps located lower than this height may be reached with comparative ease from a stepladder. Where, however, the lamps are located more than 16 feet above the floor, it is hardly possible to use a stepladder to advantage.

In a great many shop locations the various sections, with nearly all ceiling heights, are equipped with cranes which enable the lamp trimmer or repairman to reach the lamps from the top of the crane. In those cases where the cranes are thus used, great care must be exercised to prevent accidents to the wiremen or lamp trimmers by carelessness in getting on or off the crane, or through the movement of the crane while the men are at work.

Where the ceiling height exceeds 14 to 16 feet and up to, say 20 to 25 feet, and where there is no crane, the maintenance may be facilitated by mounting the lamps considerably below the ceiling within easy reach of a ladder. In very high factory bays up to 50 and 70 feet, it has been found advantageous in some cases to build a small walkway along the aisle directly along the girder line, properly fenced, for use of the lamp trimmers and wiremen. This expense, while somewhat high in first cost, will, in the case of large factories, be found to be more than offset by the prevention of accidents to the workmen and by greater ease in accomplishing the repair and upkeep work of the lamps.



FIG. 7—TUNGSTEN LAMP AND REFLECTOR, WITH WIRE GUARD

In some cases where no cranes are used the so-called automatic cut-out may be employed to advantage. By the use of this device an arc lamp may be raised and lowered by means of a rope and pulley, and as soon as the lamp is lowered, it is automatically disconnected from the circuit. In this way lamps may be placed in a position where they may easily be trimmed and the lamp is entirely disconnected from the circuit while being trimmed.

Precautions Against Breakage and Falling—Precautions against the accidental breakage and falling of lamps and accessories have

become all the more necessary, due to the general use of a larger number of lamps for given floor areas than has heretofore been the case. In tungsten systems, for example, where glass reflectors are employed, it has been found in some locations that a small wire guard can be employed to advantage as shown in Fig. 7, this guard being such as to prevent fragments of glass from falling in case the reflector is broken, or the dropping of the reflector in case it is accidentally released from the holder. In the locations referred to, this device is used for all sizes of lamps in the shop above the 60-watt size, and, where 150-watt tungsten lamps and over are used, an additional precaution is employed; namely, the supporting of the shade holder directly from the ceiling by means of two chains, where the lamp ordinarily would be suspended by flexible cord connected directly to the rosette and the socket. This feature is shown in Fig. 8, which shows a lamp of the 500-watt size supported by two small chains connected on either side of the shade holder.



FIG. 8—TUNGSTEN LAMP AND REFLECTOR WITH SUPPORTING CHAINS

Arc lamp globes, in like manner, should be surrounded by wire netting for similar reasons, and lamps of considerable weight should always be suspended by means of positively secure fittings so that there may be no danger from falling. It may be stated that, in connection with glass reflectors and incandescent lamps, a suitable shade holder has somewhat to do with the prevention of falling reflectors. The old type of shade holder made use of three small set screws which, after the reflector had been inserted, were screwed up against its neck. This scheme is open to the objection that if these screws are set tightly against the reflector when cold, after it has become heated the expansion of the glass may be sufficient to cause the reflector to crack under the strain of the set screws. A new type of shade holder makes use of a spring clip which will expand as the reflector becomes heated, thus practically obviating the breakage just referred to.

SEPARATE LIGHTING CIRCUITS

In the installation of new lighting systems in old shops where the new lamps replace an older or inferior system, there is often the temptation to supply the lamps from old circuits which may be entirely inadequate for the energy requirements. Some shops in

which the scheme of using old circuits was tried, very soon realized the difficulties involved and have provided adequate feeder supply circuits for the lamps.

Another feature to be considered is that of running motor loads on lighting circuits. In machine shops particularly, the motor load is exceedingly variable and at times will cause an excessive drop in voltage on the lines. It is urgently recommended, therefore, that wherever possible lighting circuits should be entirely separate from motor circuits so as to insure constant voltage from zero to full lighting load.

Another feature which should be given close attention is that of providing adequate wiring capacity not only for present require-

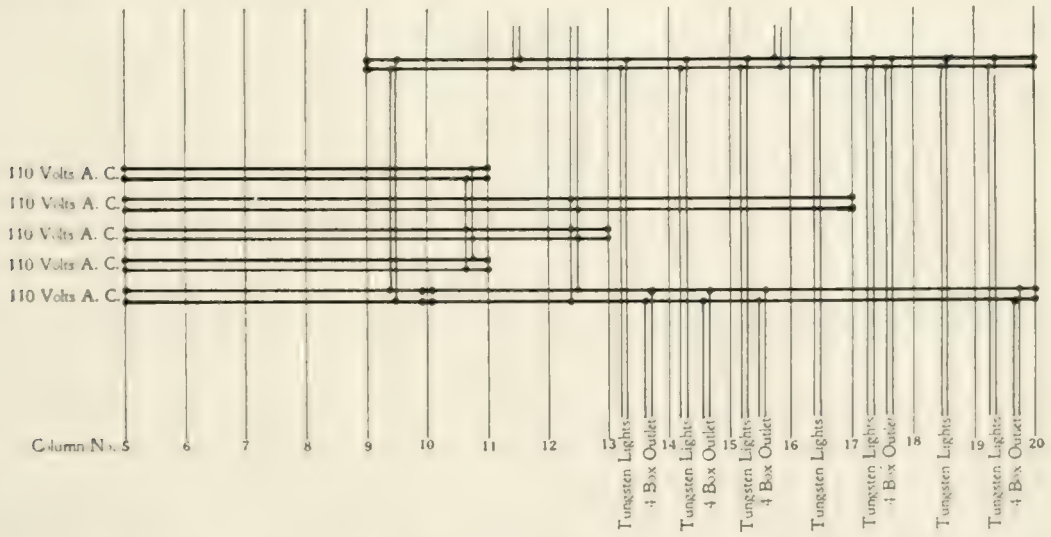


FIG. 9—SMALL PORTION OF TYPICAL WIRING MAP, SHOWING SCHEME FOR LOCATING MAINS AND CONNECTIONS

ments but for any future needs which may be later brought into service. A wiring map of one factory section is shown in Fig. 9 which was drawn up in order to rectify and improve conditions which could not be investigated with any satisfaction by a casual inspection of the mains on the ceiling. After carefully sketching the arrangement of these wires and reducing the same to a drawing, it was found quite simple to work out certain changes and modifications to improve the conditions.

ECONOMY IN USE OF WIRING MATERIAL

Where large shop areas are to be equipped with lighting systems, care should be exercised to secure economy in the use of all

wires, moulding, conduit, and the like. If the illumination design is turned over to the wiremen showing only the location of lamps with no suggestion as to the lengths of conduit and the best fittings for each case, there is a tendency, after the materials have been placed on the floor, to mis-judgment in connection with the cutting of wires or of conduit lengths. The design should, therefore, always be gone over carefully by the head wiremen for the purpose of ascertaining the best method of procedure in the location of moulding and switch circuits so as to reduce the actual material used to a minimum. This is, of course, a point of particular importance in those cases where iron conduit is used in large quantities and where accurate fittings are necessary in order to make the various lengths join up properly at the condulet openings. A prearranged plan of the conduit with accurate measurements on the drawing to indicate the various lengths and the best available fittings on the market for the various joints will, of course, tend to avoid waste.

A word may be said in passing as to the advantage of permanent as opposed to temporary wiring work. It is a temptation, especially in shops, to hang up the wires carelessly and at best in a temporary manner. Very often the wires will extend from one girder to another in such a way that a ladder employed for other work in the section is thrown against these wires, perhaps damaging, if not altogether destroying the connections. Furthermore, the wires may be installed in such a confused manner that additions to the system are made very difficult through inability to locate supply circuits or connections that are desired. It is therefore exceedingly advisable to exercise a little additional care by installing the wires in a permanent and systematic form.

MULTIPLE VERSUS SERIES SYSTEMS IN THE SHOP

Much may be said in favor of the adoption of a series system of lighting for outdoor service, both on account of the simplicity of the wiring connections and in the comparatively low cost of installation. In the shop, however, two features must be considered in connection with the choice between multiple and series arrangements. The first of these is the fact that where series systems are used, a large area of floor space is apt to be lighted from one circuit of lamps, in which event, if, say during the night turn one or two men are at work in a single section, all the lamps in the series must

be turned on in order to furnish light for these men. This results in an excessive waste of energy. A multiple or multiple-series arrangement of lamps permits one or more units to be placed on a switch. Secondly, the series system is usually associated with comparatively high voltages so that the risk to the wiremen is greater when handling such circuits for repair or upkeep than in those cases where a low voltage multiple circuit is used. The distances to be covered are also usually not great enough to secure any particular advantage for a series system. It will generally be found advisable, therefore, to install multiple circuits for industrial purposes.

The protection for wiremen and lamp trimmers is a large item and should be carefully heeded. In those cases where series circuits are already installed or must be used due to the choice of the shop manager or wiring foreman, care must be exercised to provide adequate cut-outs at each end of the circuit so that in no case will the wires be alive when the lamp trimmer is at work.

MINOR ITEMS

Much has been said during the past few years in connection with the use of tungsten lamps for industrial locations. For shop locations of more than one floor where the ceiling height is moderate, tungsten lamps have been used in large numbers. Devices have been put on the market for reducing the shock or vibration transmitted to the lamp from the ceiling. In some cases these shock absorbers are quite elaborate. It has been found, however, in large shop tungsten systems that a small piece of flexible cord from one to two inches in length connected between the rosette at the ceiling and the socket, is sufficient. The maintenance of tungsten lamps thus equipped has been exceptionally low. In general, even under the worst shop conditions this latter scheme is practically all that is necessary in order to keep the breakage of tungsten lamps down to a normal amount, particularly since the recent marked improvements in the filament and method of mounting the filament.

Where lamps must be mounted near belting it will often be found necessary to depart from the locations as given on the illumination design. Line shafting in such cases will sometimes interfere with the prescribed location, and in no case should the lamps be supported so close to the pulley that there is danger of lamp breakage

from flying belts. In some cases, however, there is such a small clearance between one line shaft and the next that it is necessary to mount the lamps rather closer than would otherwise be deemed advisable. Where tungsten lamps are suspended in such locations by flexible cord, this cord should be enclosed in an iron pipe rigidly connected to the ceiling.

CONCLUSIONS

In the foregoing some of the various items associated with lamp installations have been indicated. In general the common sense of experienced wiremen will go much further than set rules. The objection, however, in leaving the matter solely to the judgment of the wiremen is in the likelihood of a lack of appreciation of the importance of an exact location of lamps according to a design. Such men often think that a departure of six, eight or twelve inches one way or another in locating the lamps will not materially affect the illumination results. In fact, their argument is often based solely on hanging the lamps to the best advantage without respect to the illumination effect. It is for this reason that a hint is given regarding the checking up of lighting plans on the ground by the designing engineer, as the installation is being made, to ascertain that everything is in accordance with the prearranged design.

In no case, therefore, should a variation from an exact lighting plan be allowed except in special cases, and even here a check should be made after the change has been granted in order to ascertain that the results come within prescribed limits.

In general, economy does not result from cheap wiring and from locating the lamps in what may be called the easiest mechanical way. Careful installation work and the placing of the lamps so that they are easily accessible for maintenance and upkeep, although calling in many cases for a higher expense, are items which, if heeded, more than compensate for the slightly higher first cost.

METHODS OF CALCULATING ILLUMINATION

BASED ON LIGHT FLUX

E. B. ROWE

While nothing radically new is claimed for the following discussion, it is believed that those having to deal with lighting problems will find something of value. No attempt is made to cover special problems, the methods given being limited in application to stores, halls, offices, factories and similar classes of lighting service. It is assumed, furthermore, that the reader is acquainted with the common electrical terms, the photometric curve and its derivation, the various kinds of incandescent lamps, their commercial sizes and ratings, and are sufficiently versed in illumination to recognize the necessity of equipping incandescent lamps with proper globes or reflectors.

A brief summary of the common definitions of important illumination terms is given below. The definitions apply to incandescent lamps primarily, though many of them are equally applicable to any form of light source.

Light is radiant energy which affects the optic nerves and causes the sensation of sight. It is propagated through space exactly as is heat energy or radiant heat.

Candle-Power is intensity of light and is the same at all distances from a lamp in any given direction. It is generally measured in terms of the International candle, by means of an instrument called the photometer.

A Photometric Curve of any light unit is a diagram which represents graphically the variation in candle-power of the unit at different angles in any one plane. Usually this is a mean vertical plane and the candle-power at any angle is the length of the radius vector at that angle.

Mean Horizontal Candle-Power is the average intensity in all directions on the horizontal plane when the lamp is in a vertical position. Lamps were formerly rated in terms of this value—for example, the 16-candle-power carbon lamp.

Watts per Candle is the quotient obtained by dividing the wattage of a lamp by its mean horizontal candle-power. This is a *measure* of the efficiency of the lamp—for example, a 40 watt tungsten lamp giving 32.5 mean horizontal candle-power is said to have an efficiency of 1.23 (i.e. 40÷32.5) watts per candle.

Illumination is the effect resulting from light as a cause, i. e., light falling upon an object renders it visible by illuminating it.

The Foot-Candle is the unit of intensity of illumination and is given by one candle-power at a distance of one foot on a plane perpendicular to the ray of light.

The Plane of Illumination is an imaginary plane usually horizontal and taken as two feet, six inches above the floor, the ordinary desk and table level.

Mounting Height is the distance from the center of the lamp to the *Plane of Illumination*, unless it is distinctly stated as mounting height above floor.

Flux is quantity of light.

The Lumen is the unit of flux, and is that quantity of light which will give an illumination of one foot-candle over an area of one square foot.

Lumens per Watt is another way of expressing efficiency and is the quotient obtained by dividing the total lumens from a lamp by the wattage of the lamp. This is also sometimes given as *Watts per Lumen* which is the reciprocal.

Effective Lumens per Watt means the flux per watt which is effective or useful in producing illumination on the given plane.

EMPIRICAL methods of calculating and designing lighting systems have been in use for many years and have been sufficiently exact to meet commercial requirements. To be sure, they have been based on estimates as well as experience, but with the advance in the art, engineering data and science have largely replaced the former and have facilitated an intelligent application of the latter. Such empirical methods always have limitations, however, which should be thoroughly understood and allowances made if necessary. Specific empirical limitations are given in Table I.

TABLE I—PERCENT LUMENS EFFECTIVE

Ceiling Walls	Light* Light	Light Medium*	Medium Light	Light Dark*	Medium Medium	Medium Dark	Dark Dark
Prismatic clear	60	53	52	48	48	45	40
Prismatic S. F.	51	47	47	43	43	40	36
Semi-Porcelain and Aluminum	48	46	47	44	45	44	44
Opal	50	45	44	42	42	40	37
White Glass of Light Density	48	44	43	40	40	36	33
Indirect and Semi-indirect	31	28	21	25	19	17	10
Dark Enclosed	41	35	34	30	30	25	21

NOTE.—This table applies to bowl shape reflectors and bowl frosted tungsten lamps correctly installed with proper holders, except that the constants for indirect and semi-indirect hold for clear bulb lamps in the most efficient reflectors in both cases. In large buildings with comparatively low ceilings, where most of the area to be lighted is at a distance from the walls, use the figures for dark walls.

To solve any illumination problem, it is necessary to know how many lumens, i. e., foot-candles per square foot, are required to give the needed intensity under the existing conditions and with the particular lamp and reflector equipment selected.

For example, assume a large modern laundry, size 40 by 80 feet,

(Reflection conditions assumed are: Light = 60 percent reflection, Medium = 40 percent reflection, and Dark = 20 percent reflection. Some white ceilings and walls when new may approach 70 percent in reflecting value while the average ordinary condition will give less than 20 percent reflection. In such cases allow a small increase or decrease in the constants.

with concrete ceiling and walls finished in light gray. For the character of work carried on, three foot-candles average will be ample, allowing for some depreciation. Hence, the total effective lumens required is 9 600, (three times the area, 3 200 sq. ft.). This means that of the total light from all the lamps installed, 9 600 lumens must reach the plane of illumination, either directly or by reflection from ceiling and walls.

The next step is to determine how many lamps of a given size and kind will give these results. Obviously much depends on the reflector or globe used with the lamps, and on its absorption and type of distribution. With poor reflecting surface on ceiling and walls it is conducive to efficiency to re-direct most of the light at the lamp so that it is thrown directly to the working plane. By so doing, the amount of light reaching and absorbed by the walls and ceiling is a minimum. On the other hand, in cases where the ceiling and walls are light in color and have a high reflection value, it may be desirable to use a reflector with considerably lower absorption but which transmits more light to the walls and ceiling, whence some of it reaches the plane of illumination by diffuse reflection and an equal or greater total illumination efficiency is obtained. Obviously the best reflector will always be that one having the most re-direction and control of light in proportion to the total absorption, because light reflected from ceiling and walls decreases markedly as they become soiled. Just enough light should be transmitted through the reflector in upward directions to provide a low illumination on the upper walls and ceiling and give that light, cheerful aspect which is so desirable in any working surroundings.

It is quite evident that minimum possible absorption is not usually the criterion upon which the selection of a reflector should be based. Absorption is largely dependent upon shape as well as on the material from which the reflector is made and the finish of its surface. A nearly flat reflector of metal or dense opal will show less loss of light by absorption than a deep bowl of the same material. A flat prismatic glass or light density opal reflector may have an absorption as low as three or four percent, whereas deep reflectors of the same material will average about fifteen percent. This is simply because the flat shape intercepts far less light than the bowl shape and consequently the total light from the lamp and reflector is greater. Obviously the flat type of reflector does not screen the lamp filament as does the deep bowl shape and the use

of the former types is therefore limited because of bad glare effects. The strain and often permanent injury resulting from the exposure of the eye to brilliant light sources is now well recognized and the increased use of bowl type reflectors is coincident with the widespread use of tungsten lamps in commercial and industrial lighting. Flat types are to be discouraged unless they are mounted high, or in spaces which are infrequently used. All of the following remarks are based on the use of deep bowl reflectors.

Returning to the problem and conceding that reflectors are necessary, how can the number and size of lamps, to give the required 9000 effective lumens, be determined? This is where experience and the results of numerous tests combine to give an answer. Data are available on numerous installations, actual commercial installations as well as special test installations, and from these have been deduced working constants giving the "effective lumens per watt" for tungsten lamps with various kinds of glass and metal reflectors, as shown in Table I. As defined above, "effective lumens" is the percent of total flux from the lamp which is effective in producing illumination on the desired plane, that is, the useful working light. This is made up of direct light, and light reflected from walls, ceiling and in other ways, and it is largely on the relative proportions of these that the efficiency of any lighting system depends. Thus a totally indirect method is the least efficient, semi-indirect or semi-direct a little more efficient and totally direct most efficient. This assumes, of course, the use of properly designed and arranged reflectors in each case, as a direct system with poor reflectors and carbon lamps may easily be less efficient, that is, have a lower "effective

TABLE II—PERFORMANCE DATA ON 100-125 VOLT TUNGSTEN LAMPS AT "HIGH" EFFICIENCY OR TOP VOLTAGE

Rated Watts	Efficiency		Candle Power		Average Total Lumens	Av. Total Hrs. Life
	Watts per Candle	L.P.W.	Mean Hor.	Mean Sph.		
25	1.10	7.58	19.1	15.1	189	1000
40	1.01	8.07	32.5	25.7	323	1000
60	1.08	8.42	50.8	40.1	505	1000
100	1.08	8.42	84.7	66.9	842	1000
150	1.08	8.42	127.0	100.4	1262	1000
250	1.03	8.79	221.2	175.5	2195	1000
400	1.03	8.79	354	280.	3512	1000
500	1.03	8.79	442.	349.	4390	1000

lumens per watt," than a good indirect system with tungsten lamps.

The point has now been reached where the type of reflectors can be selected. Being a laundry, opaque metal reflectors are not the first choice, although they could be used. As there are no special appearance requirements beyond providing cheerful surroundings, clear prismatic reflectors can be used, as having maximum efficiency and being easiest to install correctly. The assumption regarding color of ceiling and walls was a light gray on rough concrete, and hence the column of Table I headed "Medium Ceiling and Medium Walls," should be used. Opposite "Clear Prismatic" is the "constant," 48, that is, 48 percent of the total lamp lumens are useful under the assumed conditions. The total lumens in lamps which will be required is therefore 9 600 divided by 0.48 or 20 000 total lumens. The number of tungsten lamps required is then determined by dividing this total by the total lumens for a single lamp. For convenience the performance data on the present sizes of standard

TABLE III—LAMPS REQUIRED TO GIVE 20 000 LUMENS

106— 25	watt	lamps	at	189	lumens	each
62— 40	"	"	"	323	"	"
40— 60	"	"	"	505	"	"
23.8—100	"	"	"	842	"	"
15.5—150	"	"	"	1262	"	"
9. —250	"	"	"	2105	"	"
5.7—400	"	"	"	3512	"	"
4.5—500	"	"	"	4300	"	"

100-125 volt tungsten lamps is given in Table II. From this it may be seen that to produce 20 000 total lumens will require lamps as in Table III.

Now the question is—which size of lamp shall be used? The minimum size gives best diffusion and least shadow effect, while the maximum size costs less to install and maintain, and it is in striking a satisfactory balance between these opposing requirements that the experience factor is brought to bear. In this instance, maximum diffusion is not required and the size of lamp may be governed by architectural restrictions in so far as they may make a certain arrangement of outlets desirable.

Assume that concrete ceiling beams are spaced 20 feet apart, making a total of three, and giving four ceiling bays each 20 by 40 feet in size. As there is always a gain in appearance, and sometimes a decrease in wiring cost by adopting an arrangement of outlets symmetrical with respect to the ceiling bay, the working unit in this

case is 20 by 40 feet in size. From an inspection of Table III, it is obvious that the 500 and 400 watt lamps are not suitable. Eight of the 250 watt lamps might be used but this would reduce the total wattage to somewhat less than that required on our assumption of three foot-candles. Then, too, this would call for outlets in the centers of 20 foot squares, bringing the lamps everywhere ten feet from the walls, a disadvantage likely to be serious if work is to be performed close to the walls. Going next to the 150 watt lamp it will be found that this size suits the conditions exactly. Table III gives sixteen 150 watt lamps as being the number required. This allows four per natural bay, or two for each half bay, 20 by 20 feet in size. The problem now is to locate these two outlets per square so that side outlets are the minimum permissible distance from the walls, and the distance between outlets is as near alike as possible.

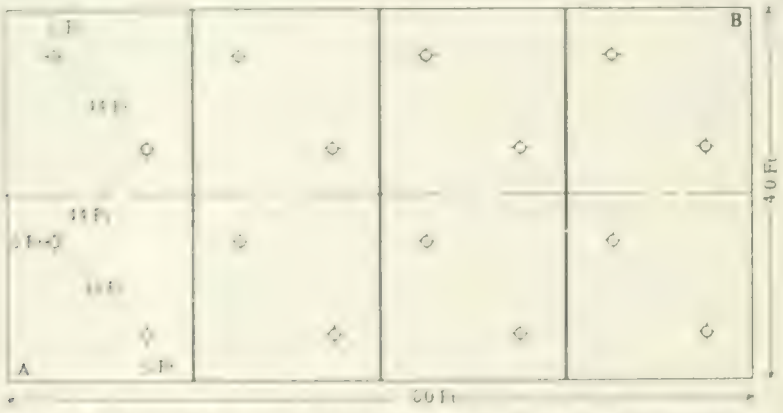


FIG. 1—LAYOUT FOR A TYPICAL ILLUMINATION PROBLEM

Arrangement of outlets to give required number and spacing of lamps, taking into consideration the location of ceiling beams.

Having drawn the 80 by 40 foot space to scale and indicated the bays and half bays, it will be found that two outlets on the diagonal of each bay at the center of each half, will give the arrangement needed. The arrangement is shown in Fig. 1. It will be noted that outlets are in the form of squares 14 feet on a side, being in four rows ten feet apart with units 20 feet apart in rows, but staggered. This brings the outside units only five feet from the walls, which is quite satisfactory.

The selection of the correct reflector and the right mounting height is a comparatively easy matter. Prismatic reflectors are available in three types giving three carefully calculated distributions, or photometric curves. These three characteristic distribu-

tions for prismatic reflectors are shown in Fig. 2, where *A* is the distribution of the bowl-frosted lamp without reflector, *B* the same lamp when equipped with the extensive type reflector, *C* with intensive type, and *D* with focusing type. These curves all give about the same total flux of light, about 15 percent less than the lamp alone (curve *A*), and yet their zonular distributions are very different, the focusing type confining most of the light directly below, while the extensive type distributes the light broadly. These three distributions are based on theoretically derived curves to give uniform illumination under fixed relations of mounting height and spacing distance between outlets, and the three types of reflectors are available for all sizes of lamps, each giving these same characteristic distributions. These fixed relations or "Spacing Constants" are indicated for prismatic reflectors in Table IV. It should be understood that uniform distribution can be secured from any of these reflectors by mounting the lamps higher than indicated by Table IV. This will give still greater diffusion of light, but ordinarily at the expense of light efficiency.

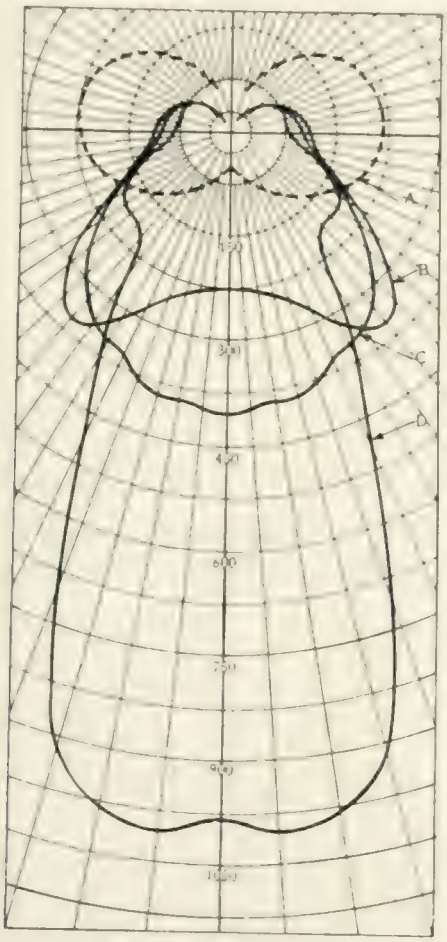


FIG. 2—PHOTOMETRIC CURVES FOR PRISMATIC REFLECTORS

A—Bowl frosted tungsten lamp.
B—Same lamp with extensive type reflector.
C—Same lamp with intensive type reflector.
D—Same lamp with focusing type reflector.

Knowing the spacing, in this case just determined as 14 feet, the proper mounting height above the plane, and hence above floor, can be calculated for each type, and the one selected which best conforms to the given ceiling height—fifteen feet can be assumed in the present problem. The selection of reflector, or determination of mounting height or spacing, is still further simplified, however, by converting the constants in Table IV to a graphical relation as shown in Fig. 3. This gives a maximum range of mounting heights from 6 to 24 feet above the

floor, and spacing between outlets from 2 to 23 feet. The method of using this diagram is readily apparent. Knowing either the spacing or mounting height, the correct reflector and its proper mounting height or spacing can be determined at a glance. Or with the type of reflector determined, the spacing for any mounting height is fixed at once.

TABLE IV—RATIO OF MOUNTING HEIGHT TO SPACING FOR PRISMATIC REFLECTORS

Type of Prismatic Reflector	Ratio of Mounting Height (Above Plane) to Spacing
Extensive	1/2
Intensive	4/5
Focusing	1 1/3

Returning to the installation under consideration in which the spacing is 14 feet it is found that extensive type reflectors call for a mounting height of about 9½ feet above the floor. This is obviously too low to secure the best diffusion and minimum shadows, so reference is made to the diagonal in Fig. 3 representing the intensive type and a mounting height of 13½ feet found. This gives a dis-

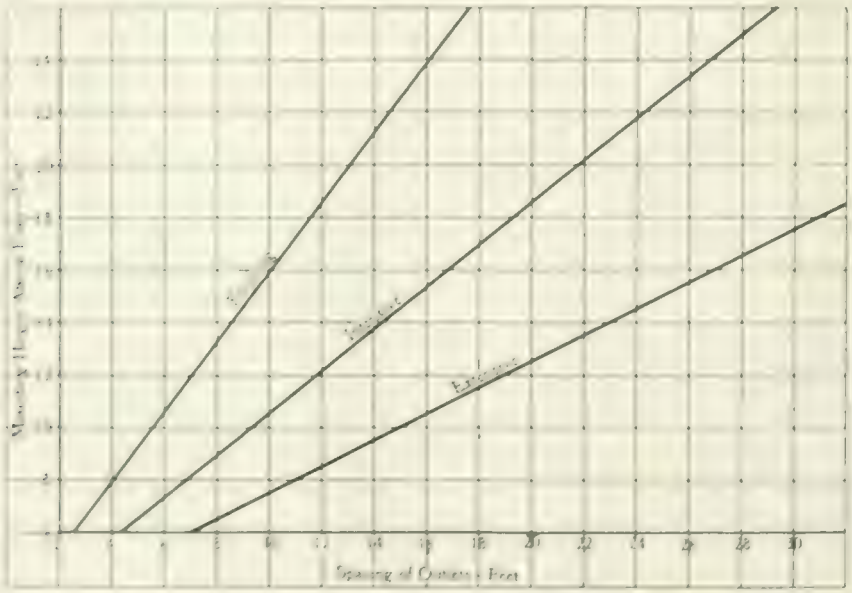


FIG. 3—SPACING CHART FOR EXTENSIVE, INTENSIVE, AND FOCUSING TYPE PRISMATIC REFLECTORS

tance to socket of about one foot on the fifteen foot ceiling, thus dropping the light units below the ceiling beams and at the same time placing them well above the line of vision, reducing glare to a minimum.

The problem then is solved and so far as the assumptions are

concerned such an installation could be guaranteed to give initial satisfaction, except that in the corners *A* and *B*, Fig. 1, the illumination might be a little low and the shadow effects unsatisfactory. This could be remedied by adding an outlet with a smaller lamp in each corner. It should be realized, however, that in actual commercial practice other important features require consideration. For example, the wiring and switch control, the probable depreciation in efficiency of lamps, reflectors and reflecting surfaces, and the frequency and best method of cleaning.

In closing it seems desirable to give a simplification of the flux method of calculating illumination above described, eliminating the use of "Total Lumens" and substituting "Effective Lumens per

TABLE V—LUMENS PER WATT EFFECTIVE

Ceiling Walls	Light Light	Light Medium	Medium Light	Light Dark	Medium Medium	Medium Dark	Dark Dark
Prismatic clear.....	5.0	4.5	4.4	4.0	4.0	3.8	3.4
Prismatic S. F.....	4.3	4.0	4.0	3.6	3.6	3.4	3.0
Steel (Porcelain and Aluminum finish)	4.0	3.9	4.0	3.7	3.8	3.7	3.7
Opal.....	4.2	3.8	3.7	3.5	3.5	3.4	3.1
White Glass of Light Density.....	4.0	3.7	3.6	3.4	3.4	3.0	2.8
Indirect and Semi-indirect.....	2.6	2.4	1.8	2.1	1.6	1.4	0.8
Bare Lamp.....	3.4	2.9	2.9	2.5	2.5	2.1	1.8

NOTE.—This table is based on the use of bowl-shaped reflectors and bowl-frosted tungsten lamps at 1.18 watts per candle or 8.4 lumens per watt, except that figures for indirect and semi-indirect units hold for clear bulb lamps. Otherwise based on the same assumptions and subject to the same limitations as Table I.

Watt" constants for the "Percent Lumens Effective" given in Table I. By this method, the "Total Watts" required is found directly and the required number of lamps is obtained by dividing this "Total Watts" by the watts per lamp. Table V gives the constants to be used in this simplified method. It is deduced from Table I by assuming a "Lumens per Watt" efficiency of 8.4 for all tungsten lamps.

Applying it to the problem just worked out, multiply the area (3 200 sq. ft.) by the foot-candles desired (3) as before, obtaining 9 600 effective lumens required. Then instead of dividing by 0.48 use the corresponding constant from Table V, namely 4.0, which gives directly the total watts required, 2 400, or exactly 16-150 watt lamps. This method is obviously more generally useful as it is easier to remember and no table of lamp lumens is necessary.

SERIES TUNGSTEN LAMPS FOR STREET LIGHTING

H. A. HUSSEY

THE lighting of streets, boulevards, parks and other public places naturally falls into two general classes, utilitarian and ornamental; the line of demarcation being somewhat indefinite. Utilitarian lighting is that required in most business districts, and in the residence sections, parks and highways where the result desired is the illumination of the roadway so that travel by night may be safe and pleasant. The greater number of street lighting installations are of this class.

Ornamental lighting is employed where the beauty by day and the spectacular effect at night is of greater importance esthetically or as a business producing medium, than is the actual physical efficiency of the illumination. In this class is included the "White Way" lighting that has become very popular in the last few years, using tungsten incandescent lamps and occasionally arc lamps.

In planning a new street lighting system or improving an old one, the districts to be lighted should be carefully examined and subdivided. Streets in each subdivision should be classified according to the amount of travel on them and the requirements for police purposes. Retail business streets and main arteries of night travel should be picked out for illumination to the highest intensity practicable, then the wholesale business districts, residence streets, suburban streets or roads which are little used at night, parks, boulevards and public squares classified according to the amount of illumination desirable. Light units should be selected and spacing arranged to fill the requirements as nearly as possible in each case. In this way the funds available for street lighting will be used to the best advantage, providing illumination where most needed and avoiding the unsatisfactory effect resulting from the use of light sources of the same type and the same spacing over practically all the area to be lighted.

The intensity which should be provided and the character of the light source most suitable for any given location must be settled for each installation with reference to local conditions. Adequate illumination of each class of streets at a minimum annual expense is the object to be attained, and great care must be exercised in selecting the types and power of the light sources and the

spacing and height of units in each class of streets to produce the maximum effective illumination at minimum expense.

When an ornamental effect is desired the actual efficiency of the system becomes a matter secondary to the designing of a system which will give the most pleasing effect by day and night, and will have the greatest value from an advertising standpoint. For situations of this kind, either arc lamps of the metallic flame or carbon flame type are available, where the expense for their installation and operation can be met. In order to be effective these lamps must be spaced rather close together and on high poles, though the latter requirement may lead to considerable mechanical difficulties. An arc system for this service leads to an extravagant use of light, and may result in such high intensities that the effect of the sign and show window lighting will be vitiated to a considerable extent. This condition must be guarded against as much as possible unless the window lighting standards can be raised.

Tungsten lamps mounted on ornamental iron standards are well adapted to this spectacular street lighting service. Standards of appropriate design which bring the lamps twelve to fifteen feet above the sidewalk, should be used and the lamps enclosed in diffusing globes. From one to five lamps are used on each standard, the majority of systems using the latter number. One-lamp standards, however, are in many cases adequate, and in better keeping with their surroundings and from this standpoint should be given careful consideration. The use of one-light standards raises a question as to the relative merits of upright and pendant globes, and the efficiencies of these methods of lamp and globe supports. Artistic design and mechanical construction are the factors for prime consideration in deciding these questions. In installations where ornamental lighting is used, the store and building fronts should be illuminated, and the extra light in the upper hemisphere resulting from using globes mounted above their support cannot be considered as wasted. Furthermore, the illumination intensity immediately around the post is usually sufficiently high, so that the light cut off by the base of the lamp support is not a serious loss.

Practically all ornamental systems using tungsten lamps are supplied with power from the commercial mains and multiple lamps are used. This avoids the use of high tension circuits in the metal standards and readily permits the installation of a few posts at a time, and additions and changes can easily be made.

From a strictly illumination standpoint the system chosen should, as far as possible:—

1—Furnish a sufficient amount of light on the roadway and sidewalk surface of such intensity and uniformity as is warranted by the character of the street.

2—Result in the elimination of dense shadows and sharp contrasts of light and shade.

3—Reduce the effect of glare to a minimum.

4—Utilize the silhouette effect.

5—Produce a steady light of uniform and pleasing color.

Street intersections being the point of greatest danger should be distinguished by a higher illumination intensity and by a change in the arrangement of the lamps. In all other respects the more uniform the illumination the better will be the result, particularly in the residence districts where a low average intensity is used. Rapid changes from bright to dark areas seriously interfere with the adaptation of the eye to either intensity, and as a result the effective light reaching the eye is reduced where most needed, thereby increasing the danger. Serious eye strain may also result. Uniform illumination of the street surface even to a low average intensity greatly increases the ease with which one can see, as the entire background (the street or road surface) against which an obstruction appears is more uniform and the silhouette effect more pronounced. It is largely for this reason that light colored road surfaces are more easily traveled at night, and require a lesser intensity of illumination than do dark surfaces to produce the same psychological effect. An extreme example of this contrast is shown by a heavily oiled street in its natural state and when covered with fresh snow, under which condition the effective illumination is much higher.

Large units are not well adapted to residence streets which, in many localities, are lined with shade trees; the foliage cuts off a large amount of light from these units which must be mounted at a considerable height to avoid glare and to secure the most satisfactory light distribution. Also where streets or roads are crooked, or the contour changes rapidly, large units should not be used. Owing to the cost per unit and the necessarily close spacing required, the total cost of large units is likely to be excessive. For wide streets and business districts a high average intensity is desirable, which may be secured economically by using some form of

arc lamp. Streets of less importance should be lighted to a lower intensity, in which case the illumination should be more uniform, for it is in streets of this class that vehicles move more rapidly, and the eye should be given every opportunity to properly perform its functions, both for the protection of the pedestrian and the vehicle driver. Arc lamps, when spaced close enough to produce sufficiently uniform illumination to achieve this result, are usually too expensive to operate on streets of this class, and the intensity is higher than is necessary.

A system of small light units, economical in operation, of low intrinsic brilliancy, giving a fairly uniform illumination is, therefore, well adapted to the lighting of a large proportion of our streets and roads. Series tungsten incandescent lamps fill these requirements admirably. Lamps ranging from 32 to 350 candle-power are available, so that by arranging the spacing and selecting the proper candle-power lamp, almost any desired result may be secured. Because of their lower intrinsic brilliancy tungsten lamps may be mounted comparatively low, usually below the lower limbs of shade trees so that all the light is available for illumination, and at the same time there will be little likelihood of trouble from glare. The light from these units is pleasing in color, absolutely steady and is quite uniform throughout the life of the lamp.

Tungsten lamp street fixtures, consisting of bracket, hood, radial wave reflector and lamp, are low in cost, so that a number of units may be installed for the same initial investment as required for one arc lamp. The spacing of units can usually be arranged to utilize the present poles where an overhead arc system is being replaced, thus reducing the initial expense to a minimum. While the efficiency in watts-per-candle is not as great for tungsten lamps as for the newer types of arc lamps, the labor and replacement cost is low, making the net annual cost, for the same minimum intensity and in many cases for the same average intensity, considerably less. An idea of the result obtainable with series tungsten lamps as compared with alternating-current enclosed lamps, for instance, is best shown by investigating a specific case.

Consider a street 50 feet wide and 400 feet between intersecting streets, with one alternating-current enclosed arc at each intersection. Four 60 candle-power tungsten lamps would cost about the same or a little less to operate per year. The tungsten lamps

are mounted twelve feet above the ground on four foot brackets and are equally spaced on one side of the street. Alternate blocks have the lamps on the opposite side of the street so that two lamps are provided at each street intersection on diagonally opposite corners, thus providing a higher illumination where most needed as well as distinctly marking street intersections. Along the center line of the street the comparative illumination on a horizontal plane at the street surface will be as follows:—

	Arc	Tungsten
Maximum Foot-Candles	0.450	0.160
Minimum Foot-Candles	0.001	0.035
Average Foot-Candles	0.057	0.082
Ratio Maximum to Minimum	450.	4.6
Minimum Tungsten to Minimum Arc	35	

These figures show conclusively some of the advantages of using series tungsten lamps in place of arc lamps, where a comparison of the systems is made with illumination on the horizontal plane as the basis. Horizontal intensity, however, is not the only criterion. When shadows, percent of light emitted reaching the working surface, uniform background, glare, visual efficiency, etc., are considered, the advantages of the small unit become more pronounced. Unfortunately these factors cannot be stated numerically.

STREET SERIES TUNGSTEN LAMPS

Street series lamps, as their name implies, are used almost exclusively for general street lighting, being operated in series with other lamps on a circuit, the current in which should be maintained at a constant pre-determined value. This method of operation imposes different conditions on the lamp than is the case with lamps operated on constant potential lighting circuits, and necessitates a design differing somewhat in general construction and method of rating from the familiar multiple lamp. Current regulation should be as close as possible, as any considerable increase in current will increase the candle-power of the lamp with an increased power consumption and lower watts per candle, but also materially decreases the life, which means an increased renewal expense. Contrary to the similar case in interior lighting, the lighting company receives no benefit from the extra candle-power intensity produced, as the usual method of payment is on the basis of a flat rate per lamp year. On the other hand, the current should not fall much below normal, as the candle-power output of the lamp will be less.

Street lighting contracts are usually based on the candle-power of the light source, which allows the lighting company to take advantage of the development of more efficient lamps. Tungsten street series lamps are, therefore, rated in mean horizontal candle-power and current, and not in total watts and volts as are the multiple lamps. Series tungsten lamps are regularly manufactured in seven standard sizes and are rated as 32, 40, 60, 80, 100, 200 and 350 candle-power, in ampere ranges from 4 to 6.6, from which range a lamp suitable for almost any location may be selected. The 40 and 60 candle-power lamps are most generally used, but many 32 and some 25 candle-power lamps are in use, largely on systems operated under old contracts where tungsten lamps have replaced the old carbon series lamp. When new installations are made the 60 and 80 candle-power lamps have been chosen as well adapted for general use, with the higher power lamps for street intersections or more important streets. The 32 candle-power lamp is suitable for sparsely settled districts or little used roads.

Series tungsten lamps have also been used to a considerable extent on arc circuits to fill in between arc lamps, and they have been standardized at the normal arc lamp currents, 3.5, 4.0, 5.5, 6.6 and 7.5 amperes. Some lower amperage lamps have been used to some extent in the past, but are no longer standard. The 4.0 and 6.6 ampere lamps are in most general use and when a new series tungsten system is to be installed lamps of either of these amperages should be selected. The 4.0 ampere lamp has the advantage of lower line loss for the same size conductor and is, therefore, preferable, other considerations being equal.

Physically, street series lamps differ from multiple lamps as they must be designed to operate at a predetermined current which is usually much higher than is ordinarily used in multiple lamps, even of the largest sizes; that is, for the same total wattage consumption, a series lamp is generally designed for a higher current and lower voltage than a multiple lamp. A filament of large diameter and short length is therefore necessary. All sizes of lamps of the same ampere rating have filaments of practically the same diameter, the variation in candle-power being obtained by changing the effective length of filament. Lamps of all candle-powers of the same amperage rating may, therefore, be burned in series. Owing to the relatively short length of filament in series

lamps there are comparatively few points of support. Care must be taken that the heat conducted from the filament at these points be a minimum, and that the heat so conducted from the filament will not vaporize the anchor material or soften the glass arbors thereby allowing the filament to sag. By interposing a link of tungsten wire between the filament and the anchor this result is accomplished. The link, being of the same material as the filament, cannot vaporize more rapidly than the filament itself and the area of the link is so arranged that most of the heat is radiated from it before reaching the anchor.

Either of two methods may be used for supporting the filament in the bulb, depending upon the length of filament required. For low candle-power lamps only a single and comparatively short loop of filament is necessary. In this lamp each end of the filament is wrapped around the one leading-in wire for a few turns and then fused, obtaining a flexible joint, with positive electrical contact. A wire arbor carries the single link necessary to support the filament. Lamps of higher candle-power require a longer filament, which is supported from a glass arbor, with anchors and links.

Street series lamps are now designed for 1.18 watts consumption per mean horizontal candle-power, the normal life being 1350 hours, when operated at rated current. On an all-night every night schedule this means an average of three renewals per year for each unit installed. In addition to renewals the cost of operating a street lamp will depend on the cost of power, efficiency of the regulator and line, labor and inspection changes, supervision, taxes, general expenses, interest on the investment, depreciation, which should be fixed somewhat by the terms of the franchise under which the company operates, and a reasonable profit for the operating company. As these factors are largely dependent upon the local conditions the actual cost for operating any given size of lamp must be determined in each case.

SELLING POWER TO LARGE MANUFACTURERS

A. E. RICKARDS*

ONE can scarcely pick up a technical publication devoted to things electrical without finding some reference to the problem of selling electric power to manufacturers. It is natural that this should be the case, first because of the many advantages a manufacturer can gain by using electric service, and second because of the desire of the power companies to build up their load-factor. Those who have given this subject much thought appreciate the fact that the day is not far distant when practically all manufacturers will be using purchased power.

To-day less than ten percent of all the power used is furnished by power companies, so the possibilities in this field are still very great. In the past, arrangements to supply power have been made with a great many small manufacturers, but only moderate success has been attained with the large ones. This must be attributed to the use of wrong methods, since those familiar with the situation know that the advantages are frequently greater, and mean more, to the large manufacturer than to the small one. Many power companies attempt to sell their power by showing that their service will be cheaper, which, with the rate quoted by the average power company, is ordinarily the case. But there are several other factors which should be given equal if not greater consideration.

The cost of power to a manufacturer is but a very small portion of his gross expenses, seldom exceeding three percent, and in many cases being less than one percent. Even if the cost of power could be reduced fifty percent, the net profits might not be increased more than one percent. But if the production can be increased, even if only a few percent, the net profit may be increased in much greater proportion. If the power companies can show the large manufacturers how production can be increased, there should be little difficulty in securing their business.

Referring again to the cost of power it is often found that the manufacturer does not know the total number of kilowatt-hours generated in his plant per year, and it is an exceptional case if he knows the correct total cost per kilowatt-hour. This being the case, to conduct negotiations upon the basis of energy cost places the power company at a disadvantage. No matter how low a rate may be offered, the manufacturer will not appreciate it unless he has accurate and correctly figured records of his costs when furnishing

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his own power. This inability to secure a fair comparison, more than anything else, is responsible for the difficulty in securing the business of the large manufacturers.

In so far as numbers are concerned, many of the power companies have done remarkably well in securing business. The following figures, covering a specific case which came under the notice of the writer, represent a fair average. These results were obtained by a power market analysis of a manufacturing center having a population of 45 000 inhabitants:—

Total number of power users	207
Number using power company's service	111
Number of connected users in percent of total	53.6
Aggregate horse-power in the territory	20 988
Aggregate horse-power connected to power company's lines	3 773
Connected horse-power in percent of the total	18

This shows that while the power company has been quite successful in securing numbers of power users, having over fifty percent of the total, the load obtained is not in keeping therewith, as only eighteen percent of the total power is connected to the company's lines; in other words, the small users have been signed up, while the larger users have not. The former were secured on the basis of reduced cost of power. But this apparent difference in relative costs did not appear to be sufficient inducement to the large consumer as, in the case of the large plant having expensive generating equipment, the cost feature is difficult to demonstrate. The owners usually know their *operating* costs but often do not take into account their fixed charges and in many cases assume too high a load factor, which cause them to believe that their cost per kilowatt-hour is very low.

Inasmuch as the selling price of the finished article ordinarily cannot be increased on account of competition, and the cost of labor and raw material cannot be decreased, the only step remaining to the manufacturer, to insure his obtaining a legitimate profit on his goods, is to decrease the manufacturing cost by increasing the internal efficiency of the factory. In the past, in order to meet these conditions, more efficient machinery has been installed from time to time. This has been carried on until, in many industries, the capital account has grown to such proportions that the fixed charges seriously detract from the gain in efficiency due to the new equipment. The time is now at hand when the profits must be obtained by increasing the internal efficiency of the plant without materially increasing the investment.

As an illustration of this, the United States census report gives

the following, concerning the nut and bolt industry. From 1900 to 1905 the number of companies manufacturing nuts and bolts increased twenty-two percent. The total capital increased seventy-five percent and the demand for the finished product increased only five percent. An analysis of these conditions is given in Table I. From this table it may be seen that, in this industry, competition increased faster than the demand. In fact the average value of the product per establishment was 13.9 percent less in 1905 than in 1900 and at the same time the capital per establishment increased 43 percent. This means a constant decrease in the net profit. To maintain the net profit about constant the manufacturer will, in the future, give more attention to the operation of his machines with a view to increasing their efficiency rather than by buying additional machines. It is an exceptional factory in which improvements cannot be made. In many shops the overhead charges upon a machine tool are two

TABLE I—RATIO OF CAPITAL TO OUTPUT IN NUT AND BOLT INDUSTRY

Year	Number of Establishments	Capital per Establishment	Total Output	Value of Product per Establishment	Percent Capital to Value of Product
1900	72	$150 000	$13 978 382	$194 000	77
1905*	88	215 000	14 687 108	167 000	130
Increase	16	65 000	708 726	27 000†	

†Decrease. *Census reports on this industry are not yet available for 1910, but conversations and correspondence with the leading men in the industry indicate that the ratio of capital to output is much higher than in 1905.

and one-half times the cost of labor, so that special attention should be given to getting the greatest number of machine hours operation possible from each machine, or in other words to make the plant produce its maximum output. This does not mean the greatest output based on the number of machines that can be located in the plant, but it means maximum output per machine. To accomplish this requires careful investigation along industrial engineering lines in order to determine how to make every invested dollar earn its greatest possible income. A careful analysis should tell what is being done at present and should also indicate how to accomplish the same operations more economically, or how to employ other operations in a better way than the old.

Industrial engineering methods, properly applied, will undoubtedly assist the public service company in selling power. The advice and supervision of experienced industrial engineers who have made

a specialty of such work is of great assistance to power companies in taking up the various problems encountered in securing large power contracts. The results of a thorough, unbiased investigation by independent engineers has in many cases resulted in convincing large manufacturers of the very substantial advantages to be secured by turning over the whole question of power supply to the power company.

Selling power involves two problems, viz., closing contracts for furnishing current to entirely new factories, and arranging to supply current to concerns which have heretofore been operating their own power generating apparatus. The first problem is the easier, seldom requiring more than the presentation of suitable arguments regarding the cost of power, economy of space, small investment, service, etc., to convince the factory management of the advantages to be secured.

A typical example of the economy of purchased power for new plants is shown in the following case. Plans were under way for a new industrial plant whose product demanded 24 hour service. The owner had contemplated driving the machinery by belts from line shafting. The engineers who had been retained, after studying the situation, recommended motor drive, pointing out to the owner the excessive friction and slippage losses incurred through belting and shafting, and the advantageous effect upon production of constant normal speed, and the many interruptions caused by belt breakage, which in a process requiring constant service, become a serious problem. Motor drive having been decided upon, the source of current became the next consideration. The owner expressed his desire for a private plant, to consist of high pressure turbo-generator sets. The average load with motor drive would be about 75 kilowatts, or about 650 000 kilowatt-hours per year for continuous service. The maximum load would require a 100 kilowatt outfit, and in order to have a reserve unit available in case of emergencies or while making repairs, it would be necessary to install two 100 kilowatt turbo-generators, which with piping, installation, etc., including the power plant building, and exclusive of motors, would cost approximately $15 000. The cost per year to operate a plant of this character would be about as follows:

Initial Investment $15 000	
Interest and depreciation at 10%	$ 1 500
Insurance, taxes, repairs, etc., at 3%	450
Coal	5 500
Water, oil, waste, etc	1 100
Labor	5 840
Total	$14 390

On the basis of 650 000 kilowatt-hours per year, the cost with turbo-generator sets would be 2.24 cents per kilowatt-hour. The motors would be the same in case of purchased power, and therefore the investment and fixed charges for these are omitted. The total cost per year for current for 650 000 kilowatt-hours, at 1.5 cents per kilowatt-hour, the rate quoted by the local power company, would be $9 750, which, compared with $14 390 with turbines, represents a saving of $4 640. Aside from this direct saving in operating cost, all investment was eliminated except the cost of motors; the operating burden was placed with the power company; there was economy of space; less fire risk, which in this case was a very important item, and the possibility of interruption in service was reduced to a minimum.

The second problem is a more difficult one. It is in these cases of selling power to replace factory plants that industrial engineering methods are of the greatest help and, in many instances, indispensable, if contracts are to be secured. By the proper application of industrial engineering principles, production can frequently be increased, the quality of the finished product can often be improved, and at the same time the cost of power reduced. There is no plant so perfect that improvements in methods or in operating conditions cannot be made.

The writer was recently called upon to consult with the owner of a plant which, he believed, was operating at its maximum production; apparently he simply wished his opinion confirmed. A preliminary survey of the machines disclosed many opportunities for improvement. Time studies on different types of machines were carefully analyzed, together with records obtained by graphic instruments. For example, on certain nut tapping machines, one man had been assigned to operate each six spindle machine. The time study showed long idle periods of the spindles due to the inability of one man to operate the machine to its capacity. Two men were placed at each machine, and as a result the output of this one department was doubled at a comparatively small expense.

If the manufacturer is shown that improvements in operation can be accomplished, and that to secure them requires the right kind of power to give constant service at uniform speed, he is readily convinced that the power company's service is advantageous. This ordinarily requires considerable work, however, and the services of trained engineers who can make the necessary tests in the shortest possible time and submit a comprehensive, intelligent report.

Many manufacturers have given little attention to correct cutting speeds. Time studies and tests of cutting speeds will often show many opportunities for improvement. For instance, drilling is one of the simplest operations performed in a machine shop and yet it is seldom that correct methods will not effect considerable improvement in this one item. In one machine shop, eight Prentice radial drills were being operated, drilling 13/16 in. holes in ¾ in. plates. Table II shows the operation before and after an investigation of the application had been made by an expert on industrial motor drive problems. Eight men were working on the above drills and formerly drilled 6 100 holes per day; they are now drilling 9 100 holes per day, an increase of 3 000 holes or 49.3 percent.

This factory was operated by shaft drive and, on nearly every machine studied, there was ample opportunity for improvement.

TABLE II—OPERATION OF RADIAL DRILLS BEFORE AND AFTER INVESTIGATION

	Former Operation			Present Operation Average
	Max.	Min.	Average	
R.p.m. of drills with presses working.....	275	185	238.7	282
Feed in inches per r.p.m. of spindle.....	0.0092	0.0071	0.0078	0.0092
Cutting speed, feet per minute	57.5	37.5	49.6	65
Average time in seconds to drill one hole.....	41.3	26	33	22

The remedy that produced the results was motor drive. This being settled, the owner contemplated installing a generating plant, until a subsequent report was drawn up showing the amount of energy that would be used per year and a comparative analysis of the cost with isolated power and purchased power. The plant now has central station service.

Each particular class of work has its most economical speed. To determine what this speed is and to build the machines up to it, comes within the scope of the industrial engineer. The following instance is particularly interesting because it shows how a few revolutions affect the output of a machine. The machine in question was a Waterbury-Farrel cold header in a large structural shop. The fly-

wheel was operating at 130 r.p.m., the machine heading sixty-five ¼ in. rivets per minute. After a study of what the dies and machine in general could stand, it was determined to speed the flywheel up to 138 r.p.m., thus making 69 rivets per minute, an increase of four rivets per minute or 2 400 per ten hour day. This is another case in which motor drive won the day and, as the concern's business was growing rapidly, they discarded their power plant to gain space and are now using purchased power.

When applied to manufacturing plants, industrial engineering means a study of mechanical efficiency. Some manufacturers are prejudiced against such investigations because they fear an interference with the shop system, or that the employes will be antagonized, giving rise to labor disturbances. However, the industrial engineer deals primarily with the mechanical problems, and works in cooperation with the owner, respecting his position relative to the labor problems that may arise. Knowing that the men may be antagonized by the use of the stop watch and similar methods, and considering also that a man will do his best when he knows his work is watched, methods have been developed whereby the necessary data may be obtained by the use of graphic meters which automatically record the information relative to the study of speed uniformity, rate of cutting, power required, etc., without any apparent surveillance over the man.

By making actual detail tests in this manner throughout entire factories, the industrial engineer is in a position to make recommendations which will improve operating conditions in various ways. His experience in other plants and industries is often of much value in locating and eradicating any inefficiencies that may exist. From his records, he knows just what improvements in operating conditions have resulted from certain changes in the various factories in which he has made investigations, and can thus determine with very considerable accuracy just what results may be secured by following out his recommendations.

ELECTRICAL OPERATION OF LIMESTONE QUARRIES AND CRUSHER PLANTS

P. N. HARRISON

ENORMOUS quantities of crushed limestone are used annually in cement mills, steel mills, and lime kilns. It is also largely used in the construction of railroads and highways, and there is a large demand for the oölitic limestone, which is highly desirable for building purposes. With the growing demand for limestone there has been a corresponding demand for more modern methods of quarrying and preparing this commodity for the market. This has been largely a matter of power application. The possibilities of the application of electricity to this work have been appreciated to such an extent that, where formerly the equipment consisted of a cumbersome engine, steam hoists, and a few mules, we now find a complete electrical equipment consisting of motor-driven crusher plant, air compressors, hoists, pumps, locomotives and rock drills.

For practical purposes the quarry and the crusher plant may be considered as a unit, since the operation of the latter is dependent upon the successful working of the former, and if the quarry is shut down in the winter season, due to weather conditions, the crusher plant must also close for lack of raw material.

ROUTINE OF OPERATIONS

In the quarry proper, drilling, blasting, hauling and pumping are the predominant operations, while the crusher plant and the pulverizing plant, if one is present, require machinery for crushing, elevating, transferring, drying and pulverizing operations in addition to the necessary air compressor for the tools in the quarry.

The drilling of the rock, preparatory to the laying of explosives for "shooting" the quarry, is commonly accomplished by means of compressed air drills. This system involves many feet of air pipes, the courses of which must frequently be changed to meet the requirements of the drillers. Recently the electric drill has proven to be entirely practicable, and the electric lines are much more easily moved than air hose or pipe lines. Recent experiments in a large quarry have shown 25 percent greater capacity for work at a reduction of 50 percent in cost in favor of this type of drill as compared with pneumatic drills. The two forms of electric drills most commonly used are the well drill and the type employing a small motor-driven pulsator or air compressor, connected to the

cylinder of the drill by a short hose. The former type of drill, due to its large capacity for work in a comparatively short time and to the fact that standard induction motors are applicable, is becoming very popular among quarry owners.

Closely following the drilling and blasting comes the transferring of the rock to the cars for transportation to the crushers. The handling of the rock in small quantities is usually done with hand shovels, while the larger quarries frequently find the steam or electric power shovel* a good investment. The method of conveying the rock from the quarry to the crusher plant is dependent



FIG. 1—NO. 4 QUARRY OF THE STANDARD LIME AND STONE COMPANY, MARTINSBURG, W. VA.

This quarry is worked from two separate levels with separate hoisting inclines, etc. The rock is conveyed to the crusher plant shown in Fig. 5, from which plant the compressed air for the pneumatic drills is also secured.

upon local conditions. If the quarry is deep a system of inclines and drum hoists will be necessary, in which event the hoists are either direct driven by motors or are supplied with compressed air from the motor-driven compressor, while if the crusher plant is located on a hillside only slight grades are encountered and the transferring of the rock from the quarry to the plant may be accomplished by means of electric tramways, which have been suc-

*See article on "Electrically Operated Shovels," by W. H. Patterson, in the JOURNAL for Nov., 1910, p. 853.

cessfully used on grades as great as six percent. Sometimes both systems are necessary, especially where several quarries supply one crusher plant and long hauls over level ground are needed to get the rock to the crusher. It frequently occurs that a quarry is worked from two or more levels at the same time in which case it is necessary to have hoists for each level, as shown in Fig. 1.

Where hauling of stone from the quarry is by means of drum hoists and inclines, varying speed slip-ring induction motors are desirable and should be substantially mounted on the same base as the hoist, to which the motor should be geared. With this method of drive the hoist can be retarded either electrically or by means of a foot-operated band friction brake during the descent of empty cars down the incline. Control of this apparatus is usually by means of a manually operated controller located in the hoist house.



FIG. 2—THIRTY HORSE-POWER INDUCTION MOTOR DRIVING SEVENTH CENTRIFUGAL PUMP IN A STONE QUARRY

The machines are directly connected through a flexible coupling, and are mounted on a heavy iron bed plate, which is bolted to a concrete foundation

The drainage of quarries is an important item in their successful and uninterrupted operation. Natural springs and surface seepage are continual sources of trouble to the quarry management and in many instances continuous operation of the pumps is required to prevent flooding of the quarry. The horizontal centrifugal pump is best adapted to this work, as the heads are very seldom over 100 feet and the water is apt to be very muddy, and contain a large amount of grit.

The pump shown in Fig. 2 is a typical example of a motor-operated pump, consisting of a single stage six-inch centrifugal pump direct-connected to a 30 horse-power wound secondary induction motor. This pump replaced the steam pump, which is seen partly dismantled in Fig. 3, and pumps an average of 528 000 gallons in 24 hours against a total head of 70 feet, at a cost but little over half that of the steam pump. The sump is ordinarily emptied in about one-half hour, and the pump then lies idle for about an hour

until the sump fills again, the capacity being large enough to care for the most unusual rainfalls without difficulty. The control is by means of a ball float in the sump and a master switch in the pump house.

For nearly all pumping applications the standard squirrel cage induction motor meets the requirements, but where automatic control is desired or where the pump is designed to operate intermittently only, wound secondary motors are preferable. In the use of either type of motor best results are obtained by the use of single or multi-stage centrifugal pumps flexibly coupled to the motor,



FIG. 3—STONE QUARRY OF THE McLAUGHLIN AND MATEER COMPANY, KANKAKEE, ILL.

The dismantled steam pump was replaced by the centrifugal pump shown in Fig. 2. The suction lift is 18 feet and the discharge is 52 feet.

under which method of drive any variations in alignment are compensated for and the standard speeds of induction motors are especially applicable.

From the quarry the stone is hoisted either directly into the crusher house, as shown in Fig. 4, or is conveyed a greater or less distance to a central crusher plant, such as shown in Fig. 5, by means of an electric tramway or by mule haulage. The cars discharge directly into the hopper of the crusher so that further handling of rock between the hauling and crushing processes is un-

necessary. Crushing is usually accomplished by the gyratory type of crusher, although this operation is often assisted by either roll or jaw crushers. These crushers may be adjusted to give various sizes of product as desired and are especially desirable in this work due to their greater capacity, as compared with the jaw type of crusher, and the continuous crushing effort exerted. Roll crushers are frequently used to reduce the rock to final dimensions after it has been first reduced in a gyratory crusher. For example, solid pieces of rock ranging as high as 10 by 5 by 3 feet can be crushed by the larger sizes of this type of crusher, after which pieces six inches and smaller can economically be reduced by roll crushers.



FIG. 3—NO. 1 QUARRY OF THE STANDARD LIME AND STONE COMPANY

This, as well as the other quarries of this company, is equipped with electrically operated hoist pumps and crushing plant, and electrically operated compressors for the pneumatic drills. The stone is semi-hard lime stone, and is used for cement and steel mills.

The power requirements of the gyratory crushers range from one horse-power per ton per hour in the smaller sizes to one-half that amount in the larger sizes, depending largely, of course, on the hardness of the rock and the average size of the blocks.

From the discharge opening or openings of the crusher the rock is conveyed to a rotary sizing screen which consists of a perforated iron cylinder revolving on an axis at a slight angle with the horizontal, the perforations increasing in diameter by steps. This machine separates the crushed rock into several grades according to size as predetermined by the setting of the crusher and

size of perforations in the cylinder. In the design of crusher plants it is necessary to know the percentages of different sizes in the product of the first crusher so that provision may be made for recrushing by the correct number and size of auxiliary crushers. The crusher capacity is commonly expressed in tons of rock crushed per hour that will pass a 2.5 inch ring while other common sizes of stone are 1.5, 3, 3.5 and 4 inches.

After auxiliary crushing and rescreening of tailings, if this is necessary, the product is passed to storage bins from which it may be loaded into cars or, if a pulverizer plant is included in the equipment, a portion of the product from the crusher plant is conveyed here and the crushed stone is further reduced by means of pulverizers, tube mills and rotary dryers, for use in fertilizer plants, potteries, etc. Squirrel cage induction motors are applicable here



FIG. 5—SUB-STATION AND CRUSHER PLANT OF THE STANDARD LIME AND STONE COMPANY

The sub-station is maintained by the stone company, and transforms current from the lines of the Winchester & Washington City Railway Company, at 22 000 volts, three-phase, to 2 200 volts for local distribution. The larger motors are wound for 2 200 volts and the smaller ones for 440. Stone is received from a number of quarries in the neighborhood, and crushed and shipped at this central crushing plant.

when the individual drive system is carried out on the crusher, screen, conveyors, elevators, etc., but where all are grouped, the combined friction load and inertia of such a group is sufficiently great to warrant the use of slip-ring induction motors. The squirrel cage motor, with the addition of dust-proof bearings has the added advantage of being practically impervious to the cutting effect of the grit that is ever present in a plant of this kind.

The policy of some central stations of prohibiting squirrel cage motors above a certain capacity upon their lines is frequently the deciding feature in favor of the slip-ring motor where the squirrel cage type would otherwise be applicable. Granting that the crushers, screens, conveyors and elevators must be simultaneously

operated, considerable belt and bearing trouble is experienced when group drive is used, which is obviated to a large extent when the individual drive scheme is carried out.

The air compressor is usually installed in the crusher plant. It is common practice to provide a smaller reserve compressor to help supply any abnormal demand or to supply the whole demand during slack seasons. Squirrel cage motors of rugged characteristics meet the power requirements under most conditions. Such compressors are always equipped with flywheels, hence the motor will be designed for high starting torque and an appreciable slip.

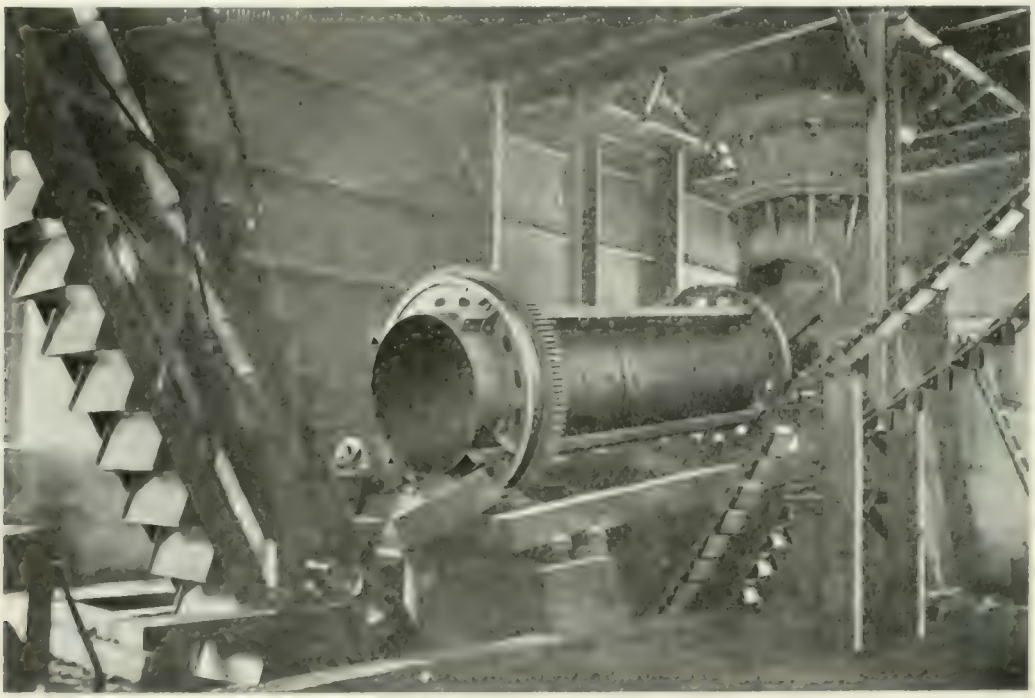


FIG. 6—GYRATORY CRUSHER, ROTARY SCREEN AND BUCKET ELEVATORS
Driven by a 200 horse-power induction motor in the adjoining room.

POWER REQUIREMENTS

This industry presents no demand for the use of low pressure steam. On the other hand, the advantages of motor drive, and the adaptability of electric power in general are conspicuous. A requisite of prime importance in quarry practice which is strongly manifested where motor drive is used, is the flexibility of the power supply for, with the frequently changing heads to which the drainage pumps are subjected, the changing lengths and grades of the inclines or hauls, the extension of air lines to meet the growth of the quarry, the varying grades of stone encountered in a quarry and numerous other contingencies, it is often necessary to call on the

overload capacity of the equipment, and to this end it is essential that a safe margin be allowed in selecting motors.

In general, the conditions call for long hour use of the power demand, such as 10 hours per day in the crusher plant and frequently 24 hour pump service. With fixed conditions the total load of such operation will be approximately constant, but it may be appreciably changed by any of the conditions cited above, while the size to which rock is broken at the crusher plant will have a large bearing on the power consumption at this point of operation. Roughly speaking the only load of an intermittent nature present is that of the drum hoists.

SOURCE OF POWER SUPPLY

The question of the source of power supply is perhaps the most important one which the quarry management is called upon to consider, and its decision will have a decided bearing on the economical and profitable operation of the plant. The average stone plant, as occurring in widely distributed territories over the country, is located some distance from the principal transportation facilities of the locality and thus, in event of the installation of a steam plant or an isolated electric plant, the item of fuel transportation becomes one of great importance even though the plant must have shipping facilities for its product. This feature and numerous others are readily obviated by adopting central station power. The availability and reliability of this source of power are well known characteristics, while flexibility of application is only another of those desirable features which obtain wherever electric power is used, no matter what the source of supply. In an industry where the load conditions are of such a fluctuating and growing nature, that source of supply which can most readily meet the increasing demands from time to time, with the least degree of interrupted service is obviously the source to adopt. As previously pointed out, stone plant conditions call for a long day's run with a frequent demand for 24 hour pumping service. This load presents an attractive field to the average central station. The power company is assured of a considerable revenue from this load and since it tends to improve the load factor of the station the company is in a position to charge a rate for its services that is mutually beneficial. It is now a common occurrence to see stone plants supplied direct from a power company's high tension lines through the medium of a sub-station maintained by the plant management, such as shown in Fig. 5, with several points of distribution for the smaller motors.

TABLE I—POWER REQUIREMENTS OF TYPICAL STONE QUARRIES

Plant No.	Kind of Stone	Average Daily Output	Used for	Number of Men	*Working Hours per Day	Horse Power Installed	†B.H.P. Motors Running	Average Monthly Power Consumption Kw-hr.	Kw-hr. per Ton Output
1	Lime Stone	150 Tons	Cement Mills	4	10	60	45	5,400	0.84
2	Blue Shale	600 "	Brick Plants	30	10	125	94	18,000	0.75
3	Soft Limestone	1000 "	Burnt Lime	40	10	200	150	30,000	0.75
4	Hard Trap Rock	1000 "	"	100	10	500	375	75,000	0.75
5	Limestone	1000 "	Steel Mills & Ballast	300	10	1,000	750	150,000	0.75
6	"	600 "	"	100	10	300	225	45,000	0.75
7	"	600 "	"	87	10	300	225	45,000	0.75
8	"	400 to 700	"	33	10	330	248	44,640	1.12
9	"	950 "	"						

*Does not include transportation of people which is frequently of 24 hr. duration.
†Plant "A"—Pumps, and relatively small accessories for grinding, high power consumption.
Plant "B"—The large consumption records for the high load factor and energy consumption.
An approximate conversion table is as follows:

2,800 lbs. = 1 cu. yd. of crushed limestone.
4,140 lbs. = 1 cu. yd. of solid limestone.

The power usage of the above tabulation will vary widely, dependent on the grade of stone, size of finished rock, amount of dressing at quarry, and the system of haulage used.

Due to the fact that commutators on direct-current motors are a decided disadvantage in this work and that a supply of direct current is rarely available, direct-current supply is hardly to be considered for any of the characteristic applications of this industry.

ACTUAL RECORDS

Data obtained by observation in plants during their operation under actual running conditions are perhaps of greater interest than theoretical values and assumed conditions. The data in Table I has been gathered from actual installations in stone plants and is intended to give a general idea of the requirements of such plants. All of these are supplied with central station power.

The following are actual records of successfully operated stone plants in which electric power is supplied by a central station:—Plant *A* especially illustrates the use of electrically driven drum hoists. Plant *B* is one where all hoisting is done by means of air hoists supplied with air from a motor-driven air compressor. This is a relatively inefficient system and is responsible for the high energy consumption noted in the table, namely 3.33 kw-hr. per

ton of rock produced. Plant *C* is a very good example of the individually driven plant.

PLANT A—CRUSHED LIMESTONE QUARRY

In this plant nine quarries are operated in connection with two crusher plants and a pulverizer plant. The total capacity of the quarries is 3 000 tons of crushed rock per day, the average daily output being 2 000 tons. The crushed product is used in steel mills and for ballast, the pulverized stone is utilized as a fertilizer. About 300 men are employed, working 10 hours per day. An aggregate of 1 255 hp in three phase, 440 and 2 200 volt induction motors is installed having a 24-hour load-factor of 11.6 percent. The electrical energy consumed per ton of stone crushed is 0.77 kw-hr., and the average monthly consumption over a period of 18 months was 77 000 kw-hr.

MOTOR APPLICATIONS

One 75 hp, 1 120 r.p.m., squirrel cage motor, direct-connected to a 6 in., 2 stage turbine pump, capacity 1 000 gal. per min., 80 ft. head.

Three, 40 hp. 1 120 r.p.m., squirrel cage motors, each direct-connected to a 4 in., 2 stage turbine pump, capacity 600 gal. per min., 80 ft. head.

One 40 hp, 1120 r.p.m., squirrel cage motor, direct-connected to a 4 in., 2 stage turbine pump, 170 ft. head.

One 50 hp, 1 700 r.p.m., squirrel cage motor, direct-connected to a 4 in., 2 stage turbine pump, 150 ft. head.

One 10 hp. 1 700 r.p.m., squirrel cage motor, direct-connected to a 1.5 in., 3 stage turbine pump for fire service.

One 37 hp, 580 r.p.m., (varying) slip ring motor, geared to a drum hoist, used for hauling 2 cars up a 300 ft., 30 deg. incline. Each car has capacity of two tons.

Six 37 hp, 580 r.p.m., (varying) slip ring motors, each geared to a drum hoist, used for hauling cars up a 100 ft., 30 degree incline.

One 37 hp, 580 r.p.m., (varying) slip ring motor, geared to a double drum hoist, used for hauling cars up a 45 deg. incline.

Two 37 hp, 580 r.p.m., (varying) slip ring motors, each geared to a drum hoist, used for hauling cars up a 200 ft., 45 deg. incline.

One 60 hp, 580 r.p.m., (varying) slip ring motor, geared to a double drum hoist, for hauling 2 cars up a 30 degree incline.

One 100 hp, 690 r.p.m., slip ring motor, belted to a 20 ft. shaft and 30 ft. of counter-shafting. Connected load:—

> One 150 tons per hr. gyratory crusher; one 30 tons per hr. gyratory crusher; one 48 in. by 16 ft. cylindrical revolving screen; one 85 ft. elevator, buckets 16 by 12 in.

One 30 hp, squirrel cage motor, driving barrel shop apparatus.

One 100 hp. 2 200 volt, 690 r.p.m., squirrel cage motor, belted to a 15 ft. shaft and 30 ft. of countershafting. Connected load:—

> One 150 tons per hr. gyratory crusher; one 40 tons per hr. gyratory crusher; one 24 in. by 65 ft. bucket elevator; one 48 in. by 20 ft. revolving screen.

One 300 hp, 2 200 volt, 580 r.p.m., slip ring motor, belted to 50 ft. shaft and 94 ft. of counter-shafting. Connected load:—

> Three 36 by 30 in. swinging hammer pulverizer mills; one 14 in. by 36 ft. screw conveyor; one 85 ft. elevator, 12 by 14 in. buckets; two 48 in. by 12 ft. revolving screens; one 9 in. by 48 ft. screw conveyor; 48 in. by 12 ft. revolving screens; one 9 in. by 40 ft screw conveyor; one 5 ft. by 22 ft. tube mill; one 4 ft. by 40 ft. rotary drier; one sacking machine; two 9 in. by 12 ft. screw conveyors, used for loading cars; one 65 ft. elevator, 12 by 12 in. buckets; one 12 in. by 21 ft. inclined belt conveyors; one 16 in. by 50 ft. inclined belt conveyor; one 16 in. by 90 ft. belt conveyor, inclined 10 deg.; two 30 ft. elevators, 10 by 6 in. and 12 by 6 in. and 12 by 6 in. buckets.

PLANT B—LIMESTONE QUARRY

This quarry produces about 600 tons of crushed limestone per day for use in steel mills. Three are 130 men employed, working 10 hours per day. An aggregate of 358.6 hp. in three-phase, 6 600 volt, squirrel cage induction motors is installed, having a load-factor of 28.7 percent. The electric energy consumption per ton of rock crushed is 3.33 kw hr., and the average monthly power consumption for a period of two years was 24 100 kw hrs.

MOTOR APPLICATIONS

One 200 hp, 600 r.p.m. motor, belted to a duplex air compressor, cylinders 25 and 16 by 20 in., 140 r.p.m., 80 lbs. pressure, supplying 1690 cu. ft. free air per min. This compressor furnishes air to eight air hoists, ten air drills, a 2 in. and a 1.5 in. duplex plunger pump.

One 50 hp, 600 r.p.m. motor, belted to 35 ft. shaft. Connected load:—

1 set gyratory crushers; one 20 in. by 50 ft. bucket elevator inclined 55 deg.; one 5 ft. by 8 ft. revolving screen; one 24 in. by 20 ft. belt conveyor.

One 8.6 hp, 220 volt, 1 700 r.p.m. motor, direct-connected to a 5 kw, 250 volt, direct-current generator.

PLANT C—CRUSHED STONE QUARRY

This quarry employs 37 men, working 10 hours a day, during which time from 600 to 700 tons of crushed stone are shipped. An aggregate of 345 hp in three-phase, 220 volt induction motors is installed, having a load factor of 8.1 percent. The electrical energy consumption per ton of rock crushed is 0.91 kw hr. The average power consumption Apr. to Nov., 1910, was 14 700 kw hrs. The consumption during the winter months is very light at this plant.

MOTOR APPLICATIONS

One 40 hp, 850 r.p.m., squirrel cage motor, belted to a 10 ft. shaft, driving a friction hoist to haul 6 by 5 by 2 ft. cars up a 20 percent incline, 150 ft. long.

One 75 hp, 690 r.p.m., slip ring motor, belted to a gyratory crusher.

One 125 hp, 580 r.p.m., slip ring motor, belted to a gyratory crusher, the shaft of which is geared to a 30 in. by 45 ft. bucket elevator (56 buckets).

One 50 hp, 580 r.p.m., slip ring motor having 2 pulleys and belted to 2 gyratory crushers which take stone from the other crushers that will not pass a 2 in. mesh.

One 30 hp, 580 r.p.m., squirrel cage motor, belted to a 5 ft. shaft, bevel-geared to a bucket elevator, consisting of 102 buckets, 22 by 10 in.

One 10 hp, 690 r.p.m., squirrel cage motor back-geared and belted to a 6 ft. shaft, which is back-geared to a 34 in. by 5 ft. revolving screen.

One 15 hp, 690 r.p.m., squirrel cage motor, back-geared and belted to a 5 ft. shaft, which is back-geared to a revolving screen which receives the discharge from the above screen.

EXPERIENCE ON THE TRIAL TRIP OF A TURBINE-DRIVEN NAVAL VESSEL

THE RECENT STANDARDIZATION AND ENDURANCE TRIALS OF THE UNITED STATES NAVAL COLLIER "NEPTUNE"

J. E. SNYDER

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The following notes on a twenty day cruise of the collier *Neptune* during last February are of special significance to naval engineers and marine architects, but are of great interest as well to all who have been watching the important developments of the last few years in the field of steam turbines. The successful application of steam turbine drive to the *Neptune*, which is the largest ship of her class that the Government has built, is briefly recounted by Mr. Snyder, who, as an expert on steam turbine operation, was detailed to supervisory inspection duty during this cruise. Probably the feature of the greatest interest to readers of the JOURNAL is the introduction of high speed turbines, which is made feasible by the use of high power reduction gears; as through them both the propeller and the turbine may be operated at the speeds that will give the greatest efficiency. Another notable fact is that the turbines are of the reversible type, having an "ahead" portion, a "reverse" portion, and a cruising element all within one casing, and are provided with means of absolute control from the bridge. During the cruise, this feature proved to be extremely satisfactory. The successful performance of the automatic governing mechanism of the turbine, which is described by Mr. Snyder, is also worthy of particular note.—(Ed.)

ON January thirty-first we boarded the *Neptune* at Newport News and the next day maneuvered toward Baltimore to pick up a cargo of coal and oil which was later to be supplied to the Atlantic Squadron—some twenty battleships located at Guantanamo Bay off the Southeast coast of Cuba—in order to equip them for a trip North. Our cruise was to include a trip to Rockland, Maine, where, with full cargo aboard, a standardization trial was to be run over the Owl's Head course, and an official endurance trial during the trip from Rockland to Boston, where we stopped to replenish our fresh water supply. During this run the weather was so cold that the hull, rigging and coaling equipment of the ship were covered with several inches of ice as a result of the continued freezing of the spray as it was deposited. During the five-day trip from Boston to Guantanamo Bay we experienced a storm lasting some twenty-two hours, which was in itself so severe an endurance test that we were all satisfied, after having successfully weathered the gale, regarding the seaworthiness of our ship. Some interesting features in this connection will be mentioned later.

The *Neptune* is the largest of the United States naval colliers

and is moreover the only ship of her size and low speed which has been equipped with turbines; she is 542 feet in length, has a beam of 65 feet and a depth of 50 feet. A broadside view is shown in Fig. 1, in which may be seen the booms and buckets for handling the coal. Her displacement is approximately 20 000 tons with full cargo aboard. The cargo consists of 10 000 tons of coal and 1 500 tons of oil. In addition she carries 2 500 tons of coal and 40 000 gallons of fresh water for her own use.

While the cargo was being loaded at Baltimore, a strong Northwest wind was blowing, and as a result the water in the bay was lowered to the extent that the *Neptune* grounded. After six hours of work with two sea-going tugs in an attempt to pull her off, it was decided to discharge them and resort to her own power. The

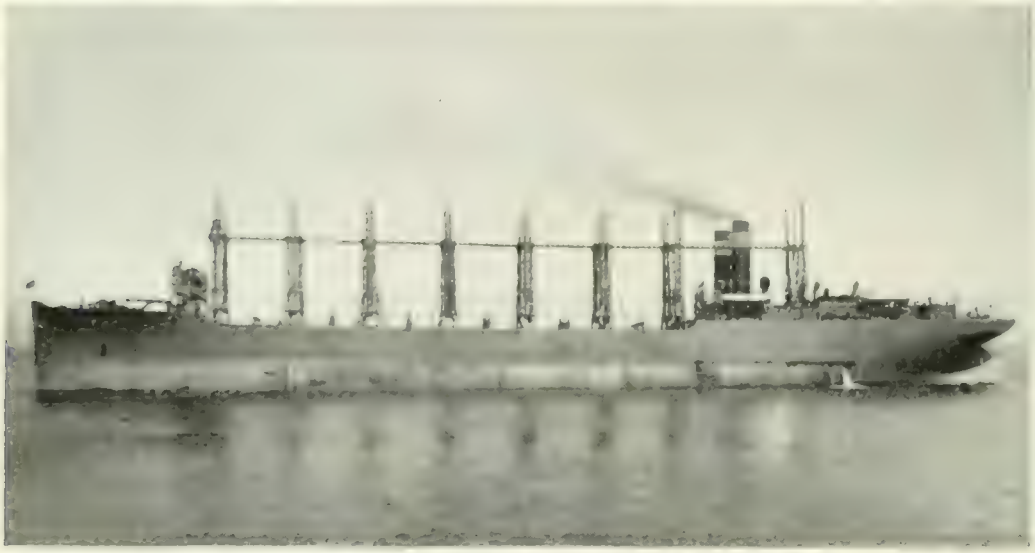


FIG. 1—THE U. S. NAVAL COLLIER "NEPTUNE"

Showing booms of coal-handling equipment. Length, 542 feet; beam, 65 feet; depth, 50 feet; displacement, 20 000 tons. Equipped with two 3 600 hp turbines, driving twin screw propellers through marine type reduction gears.

turbines were started astern and in two minutes after they were up to full speed the ship moved out into the bay, thus demonstrating the remarkable astern power of turbines of this design.

EQUIPMENT OF THE NEPTUNE

During the voyage from Baltimore to Rockland there was an opportunity to look over the ship and its machinery and equipment in some detail. The bunkers for the cargo coal are located amidships and occupy practically the entire available space. The compartments for the cargo of fuel oil are located in the forecastle. The bunkers for the collier's own coal supply are located adjacent to the stoker room which, with the boilers, main engines, and auxiliary

machinery, are located in the aft end of the ship (usually located amidships). For the cargo coal there are eight double coal bunkers. The coal is handled by thirteen grab buckets, each of 2 400 pounds capacity. There are two steam winches to each bucket, one for lifting and lowering and the other for the control of the boom. The coaling time required at Curtis Bay, Baltimore, was forty-eight hours. The discharging capacity of the collier when operating both sides, by tying up to two battleships at once, is 1 300 tons per hour.

The boilers are of the Scotch type, consisting of three main double ended boilers with eight furnaces to the boiler. Each unit is of 2 500 horse-power capacity. The Howdens system of forced draft is used, in which the blowers are so located that the air is taken from the engine room and forced through the grates into the combustion chamber. One Scotch donkey boiler furnishes steam for the coal hoisting and conveying winches; this is a natural draft boiler of 400 horse-power capacity. The main boilers are a little over twenty-one feet in length and about sixteen feet in diameter. The normal pressure is 200 pounds. The furnaces are forty inches in diameter and have a length of grate of five and one-half feet. The total grate area per furnace is 440 square feet. A tube heating surface of 15 603 square feet, a total furnace heating surface of 1 200 square feet, and a combustion chamber heating surface of 2 118 square feet, give a sum total of 18 921 square feet of heating surface per boiler.

The anchor engines are located in the forecastle. They are of the windlass improved type, capable of lifting two chains each of 160 fathoms in length and anchors weighing 9 000 pounds apiece, in twelve minutes. The carpenter shop is also located in the forecastle adjacent to the fuel oil compartments, as well as the storage bin for the ship's supplies.

The auxiliary machinery consists of a vertical duplex fire pump, a ballast pump using sea water for trimming the ship and sanitary and fresh water pumps. The water evaporation system has a capacity of twenty tons per day, and a pump is provided for the operation of this system as well as one for supplying the distillers, which have a capacity of ten tons of water per day. A suitable bilge pump equipment is provided to take care of leakage and drainage. There are also forced lubrication piston pumps. For the steam turbine condenser equipment, steam engine driven circulating pumps with fourteen inch suction and discharge are provided for circulation of the cooling water. There are two units, one for each condenser,

each of 42 000 gallons per hour capacity. The feed water heater is of the multiple coil closed type. There is also a feed water filter of the multiple coil type. There are two evaporators and two distillers. The condensers which form part of the distiller system have a condensing area of approximately 7 000 square feet.

The main steering gear which operates the rudder was built by the Hyde Windlass Telemotor Company, and is manipulated from the bridge by the wheel which controls the rudder engines (telemotors) through a steam relay. The steering gear is arranged so that in case of emergency, it can also be operated by hand.

MAIN POWER EQUIPMENT

The *Neptune* is equipped with twin screw, three blade propellers. The propellers are 14 ft. 8 in. in diameter and have a pitch of 12 ft. 1 in. The two main turbines are of 3 600 horse-power capacity each, at a speed of 1 220 r.p.m. Interposed between the turbine and the propeller shaft and direct connected to each is a Westinghouse reduction gear equipped with floating frame, the design being especially adapted to marine work. The turbines are of the Westinghouse marine type. Each propeller shaft is provided with a suitable step thrust bearing. The tests on the *Neptune* are regarded by naval men as of the highest importance because of the comparatively small size of turbines made possible through the use of the reduction gears which allow of much higher turbine speeds. The claim is made that a saving of fifty percent is effected in this way over a corresponding design of turbine for direct coupling to the propellers, or over the weight of corresponding reciprocating engines. At the same time, by reason of the high speed, the turbines used with reduction gears will effect a reduction of twenty to thirty percent in steam consumption, especially for cruising speeds, as compared with the ordinary steam rates required by any present designs of turbine driven ships or vessels equipped with reciprocating engines. It is believed that the demonstration of the practicability of reduction gearing for large horse-power, which has been made by the *Neptune*, will serve to change the entire situation with reference to the application of power to naval vessels. It will be appreciated that the reduction in steam consumption is accompanied by a corresponding decrease in the capacity of boilers required for a given horse-power capacity of engines.

All steam and exhaust connections are made to the lower half of the turbine, and the upper half of the turbine is so arranged that it can be quickly thrown back upon its hinges, thus placing both

stator and rotor blades open for immediate inspection at any time that occasion demands. The construction of these turbines is such that the steam may be turned directly into the apparatus when cold, and full speed attained in less than one minute. This is in strong contrast with the forms of construction which have thus far been used in the case of steam turbine-driven vessels for naval service, where pre-heating for from three to ten hours is necessary, depending upon the size of the unit. The floating frame of the reduction gear serves to maintain a uniform tooth pressure, a form of construction which is familiar to those acquainted with the type of reduction gear used for large stationary power units.* The method for floating the pinion frame represents a new development and provides both for an elastic motion and a separation between the casing of the pinion and the main casing of the gear. Vibration is thus very materially reduced. At the same time, the design provides incidentally for a form of hydraulic dynamometer by means of which the horse-power delivered by the turbine to the propeller shaft can be determined from a suitably calibrated gauge. The importance of such a means of correctly measuring the horse-power in the operation of ships is quite obvious. Oil under pressure for floating the frames is obtained by the pumping action of the bearings. The pressure is thus automatically regulated so as to correspond exactly with the load of the work being done.

The turbines are provided with both engine room and bridge pneumatic control. The object of the bridge control is to place the operation of the turbines under the direct control of the commander, at his own discretion, without the necessity of employing the usual system of signals between the bridge and the engine room. The control mechanism is exceedingly simple, and is so arranged that either engine may be run in either direction at any speed up to the maximum. The officer on the bridge can reverse either or both turbines from full speed ahead to full speed astern in less than fifteen seconds, which is a much shorter interval of time than it ordinarily takes to communicate signals from the bridge to the engine room with other types of control. With the speed and direction of both turbines under instant control, the ship can be turned in a very short radius.

This feature in connection with the bridge control proved itself very effective while we were at Guantanamo Bay. We had received

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*See article by Mr. H. E. Longwell on "Improvements in Marine Turbine Reduction Gear" in the JOURNAL for January, 1912, p. 69.

instructions by signal from the flagship to take a certain position relative to one of the battleships which were lying at anchor in the bay and after starting to carry out instructions our flagship sent us a message to the effect that we had misinterpreted signals. When the engines were stopped our position was such that it was necessary to turn the collier within very small space. In order to put the bridge control system to a test the *Neptune's* commander started the two turbines in opposite directions and, without manipulating the rudder, turned the ship practically as if it were mounted on a pivot.

STANDARDIZATION TRIALS

Upon arrival at Rockland on February 9th, preparation was made for the standardization trials. On the morning of the 10th, trial runs were made under such unfavorable weather conditions that it was decided to repeat them, and as the weather proved to be much more favorable on the 11th, the trials were made at once and proved to be most satisfactory.



FIG. 2—VIEW ON DECK LOOKING AFT, SHOWING RIGGING COVERED WITH ICE

The object of the standardization trials is to obtain exact data regarding the number of revolutions of the propeller shaft per minute corresponding to given speeds. For this purpose the ship is run over a measured course with the propellers revolving at a certain speed which is maintained as nearly constant as possible. The time required to cover the measured distance is duly recorded. From this data curves are plotted from which the desired relation between the revolutions per minute of the propeller and speed in knots per hour may be determined. In the case of the *Neptune,* the run was made at turbine speeds of 800, 900, 1 000, 1 100, 1 200 and 1 300 r.p.m. respectively.

ENDURANCE TRIALS

With this information established we next made an endurance run of sixteen hours from Rockland, Me., to Boston, where, as mentioned above, we stopped for fresh water supply. During this run

careful observations were made regarding speed in knots per hour, revolutions per minute of propeller shaft, steam horse-power delivered by boilers, horse-power delivered by turbines to propellers as indicated by the hydraulic dynamometer apparatus, and coal consumed, and from these observations data regarding water and coal rates, etc., and speeds maintained were calculated. The specifications drawn up by the Navy Department called for a maximum speed to be maintained on endurance trial of fourteen knots an hour. An endurance trial made last Fall indicated to those vitally concerned with the performance of the *Neptune* that the propellers were not working at as high efficiency as could reasonably be expected. Accordingly after these trials, during which the *Neptune* had failed to live up to speed requirements, the propellers were replaced by a new design, with which she was equipped for the present trials. That the trials were successful will be indicated by the fact that the *Neptune* averaged, for the sixteen hour run, a speed of 14.25 knots per hour, and showed 14.65 knots for the last four hours. This run was made in the face of a cold wind which froze the spray all over the hull and rigging, as shown in Fig. 2.



FIG. 3—THE DECK IN CALM WEATHER
View toward bow, showing bridge.

The *Neptune* left Boston navy yard on the morning of Thursday, February 15th, and we enjoyed a day of fine, clear weather. On the second day out a stiff northeasterly gale was encountered while we were off the coast of Cape Hatteras. The construction of the collier is such that a great amount of water was shipped. In

fact, during the most severe part of the storm, which continued for some twenty-two hours, the water was running even full amidships. The conditions will be appreciated by referring to Figs. 3, 4 and 5, which show respectively a view looking forward in calm weather, a similar view during the storm, and a view of the sea taken while it was running high. It was calculated that the *Neptune* shipped between fourteen and fifteen hundred tons of water when running full from gunwale to gunwale. With this excessive weight of water on the upper amidship deck there was sufficient proof of the wonderful buoyancy of the vessel, its excellent structure, and its sea-worthiness, for under similar conditions it is well known



FIG. 4—OFF CAPE HATTERAS
"Water from gun'le to gun'le."

that many ships have gone down due to the breaking of their back.

The most noteworthy thing that developed during this severe test on the *Neptune* was the fact that perhaps 50 or 75 times during the storm the propellers momentarily cleared the water while the collier was riding a heavy wave. Through the remarkably satisfactory operation of the automatic governors with which the turbines were equipped the propeller speed did not vary sufficiently from normal to cause any perceptible shock when they again struck the water. The full significance of this can be appreciated only by those who have experienced the shock which results under similar circumstances in the case of large ships equipped with engines having no governing mechanism when the rapidly accelerating propellers strike the water after an interval of clearance.

The remainder of the voyage to Guantanamo Bay was made through fine weather and the opportunity was taken of putting the bridge control feature to test under ordinary cruising conditions. The adequacy and efficiency of operating the ship by this means without the use of the rudder was fully demonstrated.

COALING

Upon arrival at Guantanamo Bay, on February 20th, we had the demonstration of the bridge control feature, when the signals were misinterpreted, as described above. We had opportunity here to see the method of coaling battleships at sea. It was remarkable

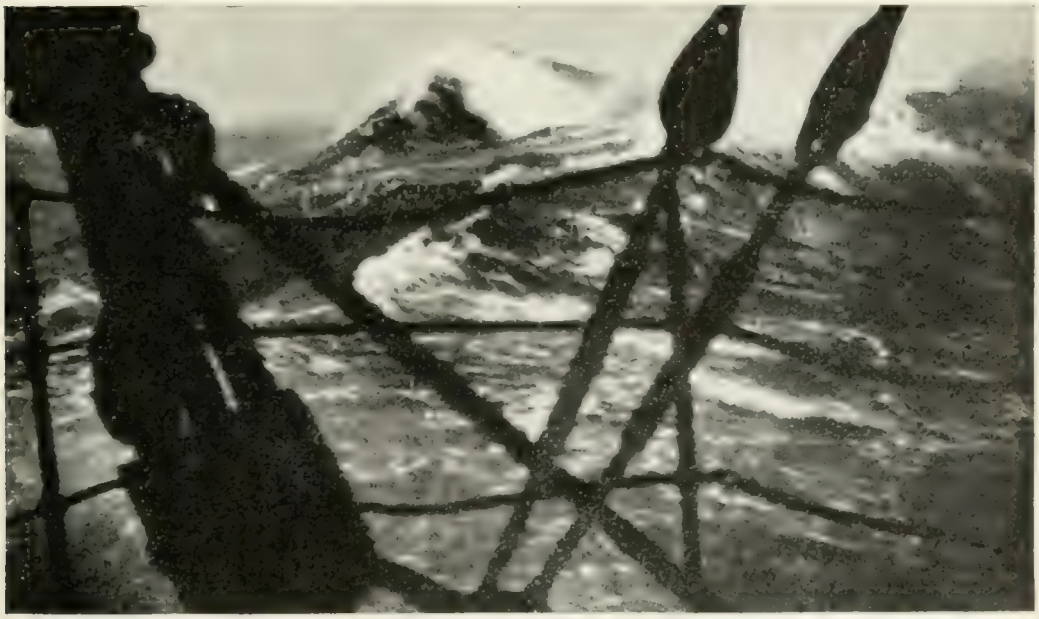


FIG. 5—VIEW FROM ABOARD THE "NEPTUNE," SHOWING HIGH SEA DURING GALE

to see with what expedition the work was carried on by the coal handling equipment of the collier.

Another device which has been successfully tried out on the *Neptune* is an attachment known as the Porhydrometer, an ingenious mechanism manufactured by the Porhydrometer Company, Ltd., of London, by means of which the amount of cargo received by the ship, or discharged from it, is automatically indicated. The *Neptune* is the first ship in the United States Government service to be equipped with this device. It works on the principle of varying hydraulic pressure with change in draft of the ship, and by its use many a dispute between engineers of vessels delivering and receiving coal may be obviated.

A MOTOR DRIVEN PIANO FACTORY

W. J. KYLE

WOOD-WORKING plants as electric power prospects may be classed under two general heads;—those using dry kilns, such as furniture and piano factories, and those not requiring kilns, such as mills and general wood-working establishments. In studying the first class, the value of using exhaust steam from the engine is usually greatly over-estimated and many times the power engineer gives up without a careful analysis of the conditions; in fact, he often does so before seeing the plant at all. The problem here, is to educate the manufacturer to conserve his waste products for the purpose of heating his kilns and securing the same economies from the consumption of wood waste as he would if he were paying money for coal, as it represents the same thing. The second class presents the difficulty of disposing of the waste, but it is by no means an unsurmountable one if the power man will exercise a little ingenuity in looking for a solution.

In the case of a furniture manufacturer, where the use of exhaust steam is a factor and the operating load is not over 300 horse-power, there is no reason for giving up hope merely because the first thing the manager says is that he burns as much coal during the fourteen hours that the engine is shut down, as he does while it is running, as an analysis of this statement will reveal the cause. In the first place he is firing for heat only during the coldest fourteen hours of the twenty-four and during the remaining ten hours he is usually allowing no fuel value for his offal, to account for the coal increase during the non-operating hours.

In addition to this, it is quite commonly found that the heating system is inadequate and poorly installed, and that in many cases return pipes are higher than the steam supply line and consequently require a high pressure to force the air and condensation ahead, the steam doing the work by expansion. The owner thus gets the impression that he must carry a high pressure in order to get the temperature required and pays no attention to the question of the proper amount of radiation, circulation or intake and discharge of fresh air in the kilns proper. These are things he no doubt knows about but he does not know the relation each bears to the other. If the power solicitor will start at the kiln and talk

efficiency of operation and steam heating economy before discussing kilowatt-hours and electric power, he will get the confidence of his prospect because he is talking about something in which the prospect is very much interested, and which he understands, and finding that the solicitor displays a knowledge of factory operation, the prospect will come to the point of kw-hours without any forcing, because he is interested.

One plant of this type which the writer investigated was using central station power, but the conditions were not as favorable as they could have been. The kilns contained 32 400 cubic feet of lumber, and during the day they burned the offal with no attention to economy, the steam pressure ranging from 50 to 125



FIG. 1—GENERAL VIEW OF INTERIOR OF FACTORY OF SCHUMANN PIANO COMPANY
Showing freedom from obstruction of aisles and good lighting. Conditions after shafts and belts were removed.

pounds, the blowing off point, and during the fourteen hours shut down, they burned two tons of coal, the condensation being trapped and returned to the boiler with a pump. It was found that at least 30 percent of the offal was wasted during the day, and with a vacuum system they could have cut the total fuel in half.

It is necessary for the central station to do the engineering for this class of business because the manufacturers must be educated in efficiency and economy of steam consumption, and the engineering is too complicated for the average business man to understand. Again, this class of plants frequently include an Underwriter's fire pump, which requires 50 pounds steam pressure

at the throttle for 24 hours per day. The Underwriters' lowest estimate for maintaining steam for this pump is $365 per year, which does not include repairs, oil, waste, packing, etc., and applies only where the steam pipes are covered with the best of materials and the cylinders well jacketed to reduce the condensation, and when the whole proposition is figured out from an operating standpoint, it can readily be seen that the higher initial cost of an electric pump is justified. If the conditions are right, a centrifugal pump can be selected which will reduce the cost of the pump, as

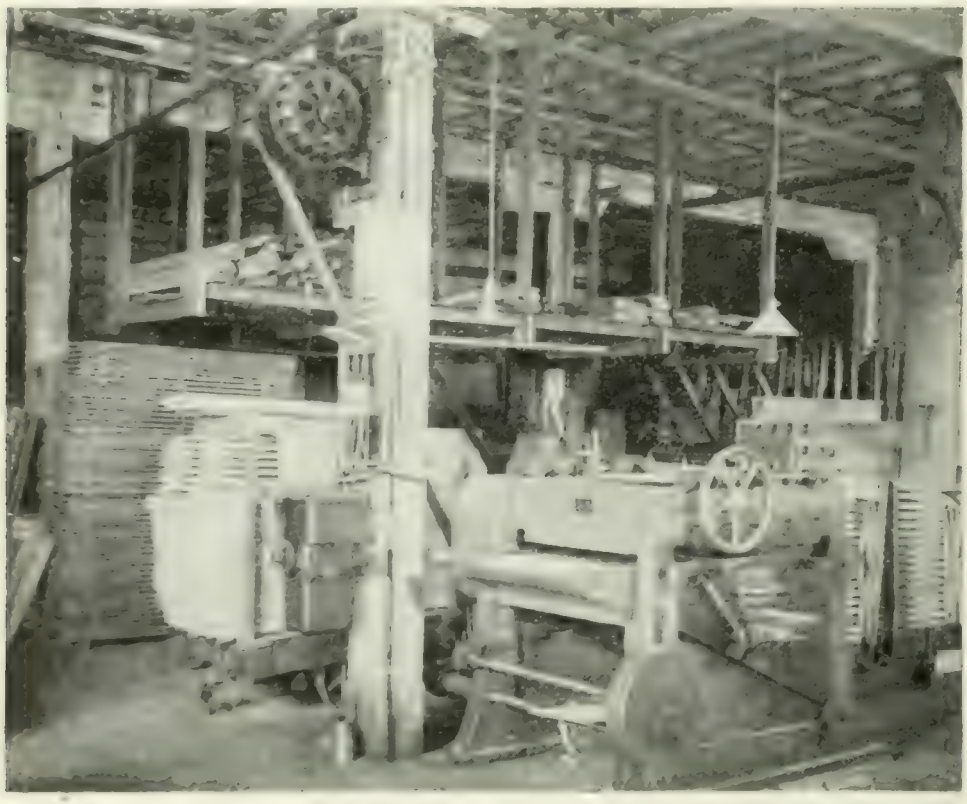


FIG. 2—MOTOR DRIVEN SCRAPER

Note the ease with which a motor may be mounted in any out-of-the-way location, and the convenient location of the starting box and switch. This construction provides ease of control and minimum wiring.

well as use a high speed and consequently a cheaper motor. Furthermore, the valve maintenance of the duplex outfit can be avoided and a very simple arrangement provided. The pump will cost nothing for operation unless it is called upon in case of fire and can be made automatic or non-automatic, depending upon what companies the customer is insured with. There are many conditions which differ with different installations and the power engineer must work out the individual case. An automatic 1 000

gallon per minute Underwriters' centrifugal fire pump ordinarily costs about $2 400, while a duplex automatic outfit costs about $3 000, but the water supply conditions must be understood before selecting a pump.

The Schumann Piano Company of Rockford, Ill., have a most modern and up-to-date system of electric drive taking central station current exclusively for their factory. About eight years ago this company moved into a building which was formerly occupied as a chair factory and until recently the old engine and shafting were used by the Schumann Company. Owing to the increased demand for high grade pianos the management decided

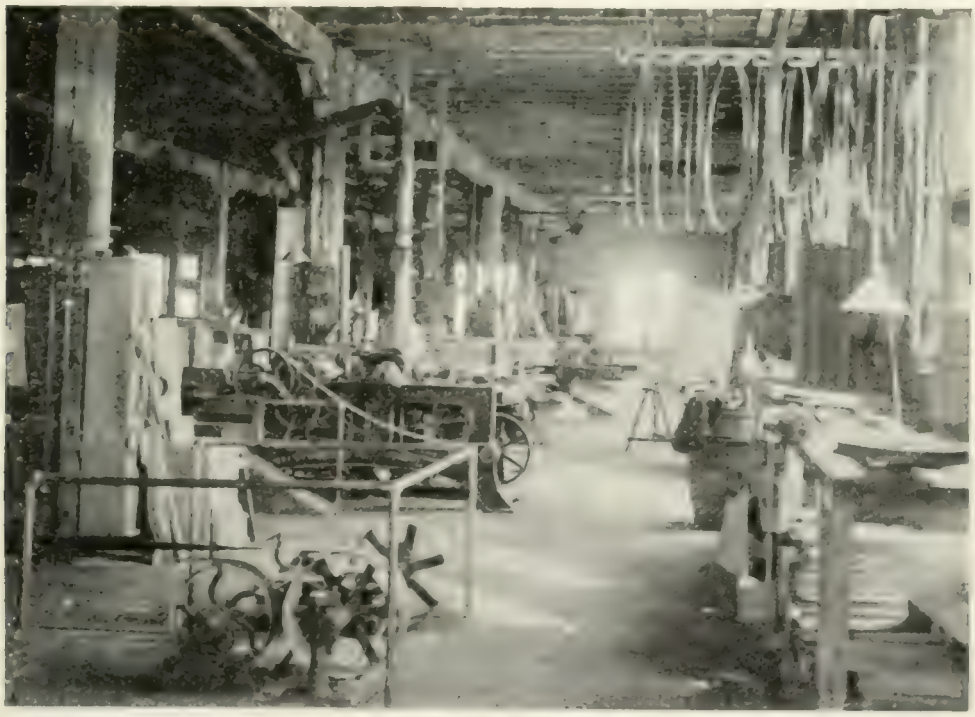


FIG. 3—VIEW ON FIRST FLOOR

Showing absence of motors, which are mounted on the ceiling of the basement.

to greatly increase their capacity. The question of power arose, and in going over the old plant and shafting it was found that the entire plant would have to be remodeled in order to have an up-to-date factory. With the old arrangement the machines were scattered around the large mill room with no view to having each machine in the most convenient place.

A little sceptical at first, the management was soon convinced that central station power at a reasonable figure per kw-hour would admit of a more systematic arrangement of machines and save at least 10 percent of the cost per hour, even with the dry

kilns to supply with steam. In laying out the reconstruction of the plant, consideration was given first to routing the raw material through the factory; second, to the convenient location of the switches and auto-starters, and third, to the motor location in order to save floor space and reduce the number of belts. In all, 177 horse-power of squirrel cage induction motors were installed, ranging in size from ½ to 40 horse-power, according to the requirements of the machine, most of them being located on the rafters, near the ceiling, and driving through the floor to the machines located on the floor above. Practically all of the belts are covered by wooden troughs, or so enclosed as not to endanger the workmen.

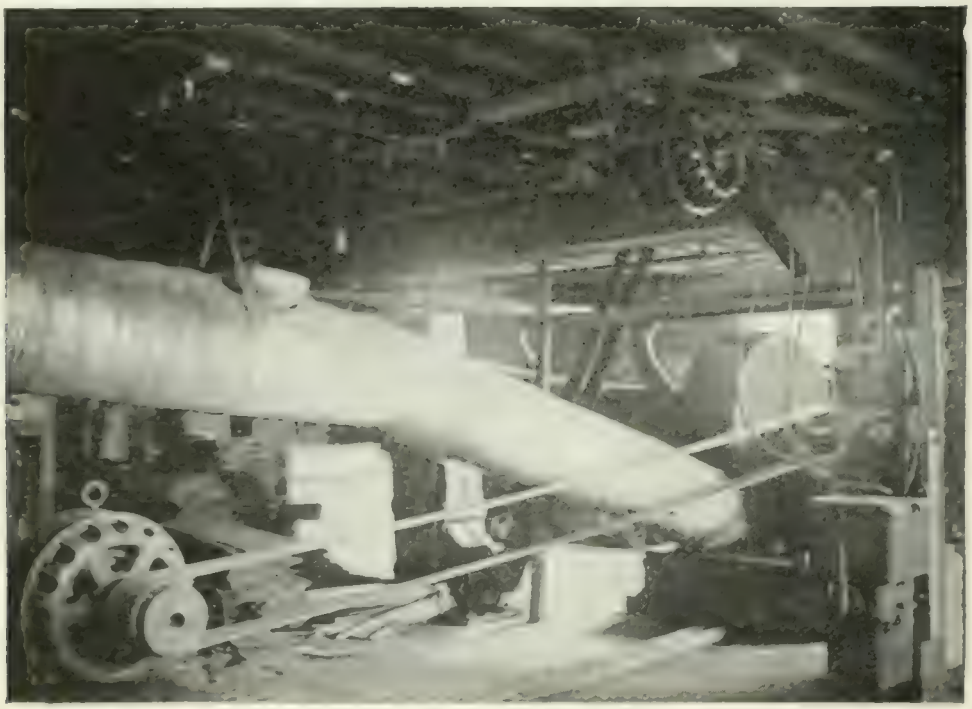


FIG. 4—FORTY HORSE-POWER, 1,700 R.P.M. INDUCTION MOTOR, DRIVING A 55 INCH BLOWER

Also a motor mounted on a ceiling to drive a machine on the floor above.

In addition to these motors, electric glue pots have been installed, and have proven more than satisfactory, inasmuch as they have displaced over 600 feet of steam piping and saved considerable time by having the glue at the man's side ready for immediate use, where before it was necessary for the workmen to walk to the center of the room for his glue, a distance in some instances, of over fifty feet. The wiring is protected with iron conduit wherever there is a possibility of mechanical injury, and all meters, main switches and current transformers are located on the side walls, in a cabinet, which allows free access when opened.

The present electrical equipment has made a remarkably large saving in space and has done away with over 1 000 feet of shafting. By studying the requirements, the engineer who laid out the new installation was able to place the machines in such a position that now the wood comes from the dry kilns and passes from one machine to the next until it is ready for the different departments. Formerly, when the machines were placed where they were most convenient to the shafting, it traveled about the mill room several times.

The cellar was at one time a mass of shafting and belting, which has now been removed and the entire basement has been added to the factory as available floor space. It is the intention of the management to have trucks drive into the cellar and unload directly into the elevator, and in this way facilitate the handling of material.

When working up the data, one thing was especially noticeable; namely, that at least 75 percent of the machines were operating at less than normal speed. These speeds were brought up to the normal, thus materially increasing production.

This plant has been operating with motor drive nearly two years, and is running well within the original estimate of power consumption and dry kiln heating. The waste wood is amply sufficient to furnish fuel so that 60 pounds of steam can be carried for the fire pump and dry kiln during the day and in addition to the offal, the night watchman uses a thousand pounds of coal to carry him over the night. The dry kiln is 72 × 22 feet, with a capacity of 3 600 feet of lumber.

The following points have been demonstrated in this wood-working shop: the initial cost of increased power secured from a central station is less than the installation of a steam plant and shafting; a great gain in floor space has been made, and the operating cost compares favorably with the best isolated plant figures. One thing that might be of particular interest to the power man is that the offal in this shop is small—practically nothing when compared with regular wood-working establishments.

The time spent in changing over was three and one-half days, but only two working days were lost as Saturday afternoon and Sunday were included in the time. The data of the more important machines is given in Table I.

The aggregate capacity in motors is 177 horse-power; the 24 hour load factor is 9.4, and the consumption per piano is 60 kw-hr. The peaks are practically all less than 10 seconds duration. The kiln dried lumber is of Oak and Maple, which are the principal woods used in the construction of the pianos, outside of the veneer. The total power consumption during 1910 and 1911 averaged about 9500 kw-hours per month. About 150 men are employed, working 10 hours per day. This plant has given excep-

TABLE 1—MOTOR REQUIREMENTS FOR WOOD WORKING MACHINES AT SCHUMANN PIANO COMPANY FACTORY

Machines.	Motor HP.	Peak HP.	Ave. HP.
14 in. swing saw	3	5.4	2.5
14 in. rip saw	5	10	4
15 in. rip saw	5	10	4
24 in. face planer	5	6	
20 in. face planer	5	4	
20 in. face planer	5	4	2
28 in. planer	7.5	10	6
planer	10	13.4	10
continuous jointer	10	12	7
boring machine	1	1.3	1.3
14 in. double saw	5	10	5
sticker	10	15	11
two-headed shaper	5	6.5	5
band saw	3	3.3	3.3
drum sander	3	3.3	1.5
glue plant	0.5	1.0	0.3
12 in. rip saw	5	4	3.4
belt sander	5	4.7	4
14 in. extension drill	1	1.5	1
48 in. blower	40	40	35
back cleaner	5	10	3

tional satisfaction in every detail. It has been visited a number of times by manufacturers of the same product from other parts of the country and they have become so enthusiastic with the installation at this factory, that several of them have declared that they would make changes in line with the ideas carried out at the Schumann Piano Company. Since motor drive has been installed, the product has increased 20 percent with no increase of the power bill over the estimate given during the negotiation and with a decreased cost of shop labor.

BATTERY CHARGING EQUIPMENTS FOR ELECTRIC VEHICLES

T. H. SCHOEPF

THE successful development of electric vehicles, both pleasure cars and commercial trucks, has resulted in such reliable and economical operation that they are being installed in large and increasing numbers. Concerns which own many cars usually equip private garages, but there is an increasing demand for more public garages wherein owners of one or more cars may have them cared for. In the public garage, cars must be handled which are equipped with a wide diversity of electrical apparatus, the storage batteries, in particular, differing in type, capacity and number of cells. In order to secure flexible operation in a garage, it is desirable that the battery charging equipment be arranged so that the batteries of any car may be charged from any circuit.

In order that the batteries may be charged economically, the energy should be supplied at a voltage closely approximating that required at the battery terminals and with a minimum of ohmic resistance introduced in the charging circuit to secure voltage regulation. In general, the batteries may be separated into two classes as regards charging voltage, i. e., 60 volts and 110 volts, but the voltages have to be adjusted to suit the number and type of cells and state of charge. Therefore, the switchboard should be equipped with a double bus-bar system and arranged so that each charging circuit may be switched onto the bus-bar whose voltage is best suited for the individual battery. Ordinarily, a single bus-bar is used and a rheostat is introduced in each charging circuit so that the voltage may be regulated to that required at the battery terminals. A rheostat so proportioned that the ohmic resistance may be raised over sufficiently wide limits to regulate the voltage, will be large and costly and the waste of energy prohibitive. A careful analysis of the requirements for battery charging, and a study of the means by which these may be fulfilled satisfactorily, leads to the conclusion that the bus-bar voltages must be capable of variation over a wide range without interruption. A compilation of data on the batteries now in use shows that the voltage must be varied from 60 volts to 110 volts, although there are a few batteries requiring less than 60 volts.

For the purpose of discussing the battery charging problem, a particular garage will be taken for example. The cars cared for therein are equipped with batteries as indicated in Table I. Each night batteries have to be charged and cars washed, inspected and oiled; therefore all the cars are not on charge at the same time although sufficient charging circuits are provided so that the 70 cars could be charged at the same time if necessary or desired.

At present the energy is taken from a three wire 230-115 volt supply system and the voltage is reduced to that required at the battery terminals by the introduction of ohmic resistance into each charging circuit. The wastefulness of this scheme renders its continued use highly undesirable and it is planned to make use of a scheme based on sound engineering principles. Two motor-generator equipments will meet the conditions most satisfactorily, each set to be of 75 kilowatts capacity, and each of the generators to be shunt wound so that its voltage may be varied from 60 to 125 volts by

TABLE I—BATTERY DATA OF CARS IN A PUBLIC GARAGE

No. of Cars	Type of Battery	No. of Cells	Charging Amp.		Volts	
			Start	Finish	Start	Finish
10	Lead	24	28	12	52	61
30	"	28	28	12	60	71
20	"	40	22	9	86	102
10	Alkali	60	30	30	102	111

field adjustment. The advantages secured are as follows:—Either or both machines may be connected to either of the bus-bars of a double bus-bar system and the voltage regulated to best suit the batteries being charged; if one machine should break down the other set can be used to charge any batteries that may be connected in circuit and the operation of the garage continue without serious interruption. When few cars are to be charged, the second motor-generator set may be shut down and the load factor continue to be high.

In order to reduce the cost of the equipment the double bus-bar may have a common negative which permits single-pole switches in the charging circuits, these switches to be double throw so that each circuit may be switched on to either bus-bar, and thus the charging rheostats may be cheaply proportioned and at the same time be large enough for use on any battery connected to a bus-bar of its proper voltage classification. If the charging platform or room is

situated some distance from the switchboard a system of lamp indicators may be installed so that the car operator or battery man may signal the switchboard attendant that a particular charging circuit is to be switched on to circuits having one or the other voltage classifications.

The electrical connections for a system as outlined above are shown diagrammatically in Fig. 1 with one battery charging circuit only indicated, the other circuits being exactly similar. It will be noted that the ammeter for the battery circuits is connected so that the current in any one circuit or the total current for any number of circuits may be observed. If all of the cars are started charging at approximately the same time, it will be seen by reference to Table I

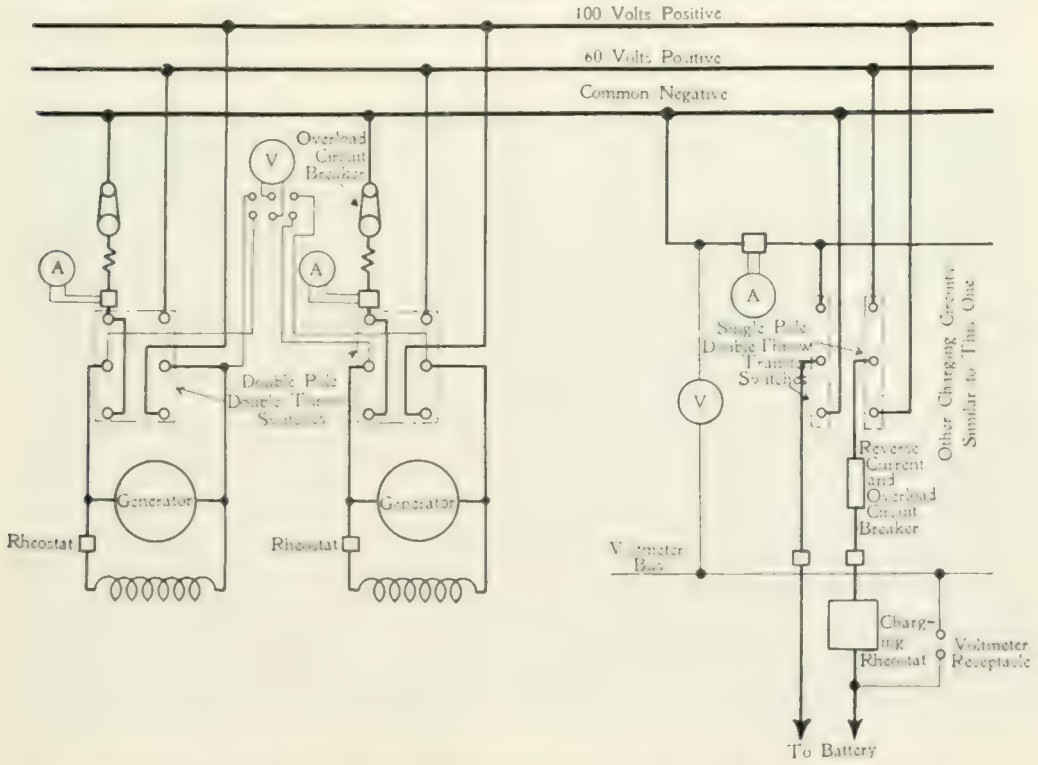


FIG. 1—WIRING DIAGRAM FOR SWITCHBOARD FOR TYPICAL GARAGE OR LARGE COMMERCIAL AUTOMOBILE CHARGING STATION

The current and voltage in any charging circuit can be read by a single ammeter and voltmeter.

that one generator is to be adjusted for 60 to 65 volts and the other for 102 volts, which results in a minimum dissipation of energy in resistance of each circuit. However, if the charge of some of the batteries is further advanced than others, the bus-bar voltage must be raised at an early time and the charging rheostats adjusted for the batteries whose charge is not so far advanced. But the increase in bus-bar voltage is by very small increments depending on

the fineness of the field resistance, so that the conditions of charging continue to be highly economical. As a matter of fact, a plant of this size will require the constant attention of a switchboard man, so that one or more batteries can be switched off for a short time or the charge continued at a lower rate if higher economy may be secured thereby. In this connection it should be borne in mind that the highest economy may be secured only by having the bus-bar voltages as near as possible to those necessary at terminals of the batteries and this should be the voltage required by the battery whose charge is most advanced.

Records show that electric vehicles, particularly trucks, operate on an average of 24 days per month, or 288 days per annum, and each battery on an average is discharged two-thirds of its rated capacity. Therefore, a garage equipped to care for the batteries as indicated in Table I, will have to deliver to the batteries 647 kilowatt-hours per day or 180,336 kilowatt-hours per annum. Assuming that the average efficiency of conversion is 75 percent for the motor-generator set, the demand from the supply system will be 248,448 kilowatt-hours, which at four cents per kilowatt-hour amounts to $9,938 annually. Practically the whole of this load comes at the "off peak" period, hence this source of revenue should appeal to central station managers as most desirable and to be encouraged. It may be of interest to note that an average of 9.24 kilowatt-hours per day is delivered at the terminals of each vehicle, which, corrected for efficiency of conversion amounts to 12.32 kilowatt-hours at the supply mains. These estimated costs for power, when compared with published data, may be considered as conservative, in that no factor has been used to correct for periodic overcharging of the batteries.

STREET LIGHTING BY METALLIC FLAME ARC LAMPS

W. P. HURLEY and C. B. PADON

RECENT developments in the design of existing types of electric lamps, as well as the introduction of new and improved types, have made available more suitable illuminants to meet the requirements for city and suburban street lighting. The general interest manifested in the application of scientific principles to illumination problems has included streets, parks and public areas, as well as the industries. The problem may be considered as two-fold:—first, the securing of highly efficient lamps from the physical standpoint; and second, the making of an analytical study of the requirements of street illumination.

The old open carbon arc lamp has, in the majority of cases,



FIG. 1—TYPICAL INSTALLATION OF METALLIC FLAME ARC LAMPS

been replaced by the enclosed carbon arc lamp, which in turn has been superseded by impregnated carbon lamps or lamps using electrodes of a metallic nature. This last type, while comparatively new, has met with a wide demand due to its excellence in the matter of light giving properties, low maintenance and efficiency of operation.

ILLUMINATION FACTORS

The most important consideration in the illumination of streets is the production of a fairly uniform and sufficiently intense light on the street, without excessive glare. The conditions which affect this result may be enumerated as the spacing distance, the mounting

height of the lamp, the distribution curve of the lamp, and the type of globe or reflector used. It is desirable that general rules should be followed for the location of street lamps, but difficulties are often encountered due to the necessity of locating lamps at arbitrary locations. Lamps are commonly placed at street corners or crossings, and the great diversity of existing spacing distances is largely explained by the irregularities in the length of city blocks.

The uniformity of street illumination is, of course, largely dependent on the distribution curve of the lamps used and, obviously, if the spacing distance is great, the distribution curve must be such that the light will be thrown in large quantities at relatively small angles below the horizontal in order that points midway between lamps may be illuminated to approximately the same degree as those portions of the street near the lamps. The distribution curve of the metallic flame arc lamp is adapted in an excellent manner to this purpose.

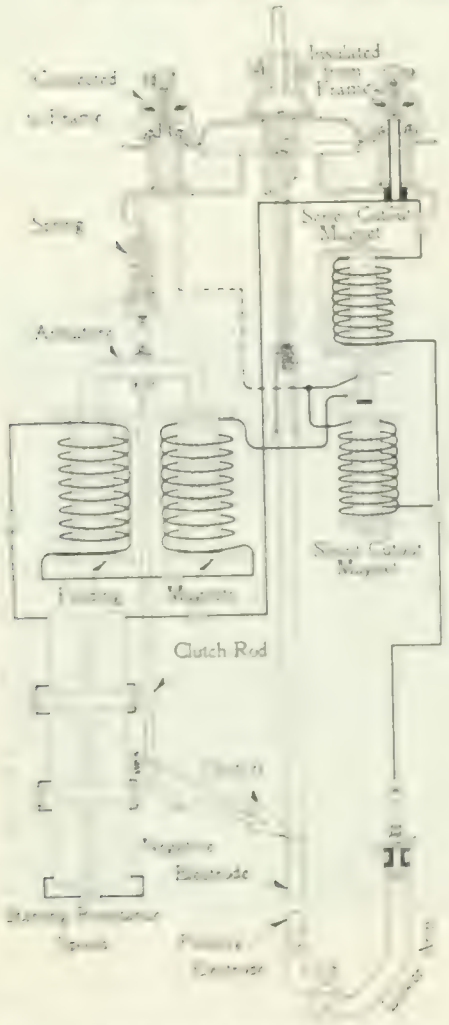


FIG. 2—[illegible] OF METALLIC FLAME SERIES ARC LAMP

Cost features undoubtedly form one of the major items considered in connection with street lighting systems, and it is of interest to note that the cost of operating metallic flame arc lamp systems in connection with mercury arc rectifiers, including the various items from the coal bin to the lamp itself, together with interest and depreciation on the original investment, is actually less than for any former system of arc lighting giving equivalent illumination. This system further yields considerably greater average illumination for a given expenditure of energy than any of the older systems, and in those cases where an existing installation of arc lamps of the older type furnishes what may be considered adequate light, the introduction of metallic flame arc lamps may greatly reduce the energy consumption and maintenance costs, as well as maintain an equal, or even greater, amount of illumination.

Sometimes it is found advisable to use the metallic flame arc lamps in the business districts, while outlying sections may be lighted by series tungsten lamps which have been designed with current ratings such as to permit their use in series with arc lamp circuits. This gives an exceptionally flexible system which has been used in a large number of cases with excellent results.

ITEMS CONNECTED WITH THE LIGHTING EQUIPMENT

One of the objections in the past to the use of direct-current series arc lamps has been the question of power distribution. The necessity for using constant current arc generators has frequently caused the economy and superior qualities of direct-current series systems to be overlooked in favor of the more efficient method of

TABLE I—WATTS CONSUMED IN ARC LAMP CIRCUITS

Type of Lamp and Source of Power	At Lamp Terminals	Line Loss per Lamp	Regulator Loss per Lamp	Generator, Motor and Trans.	Total Watts per Lamp at A. C. Bus-Bars
4 Amp. D. C. Series Metallic Flame —Operated from Mercury Rectifier	272	10	23		305
6.6 Amp. D. C. Series Metallic Flame —Operated from Mercury Rectifier	450	25	40		515
7.5 Amp. A. C. Series Enclosed —Oper'td from Constant Cur. Trans.	468	35	20		523
6.6 Amp. D. C. Series Metallic Flame —Operated from Arc Generator	450	25		210	685
6.6 Amp. D. C. Series Enclosed —Operated from Arc Generator	495	25		230	750

distribution made possible by the use of alternating current. This attitude is no longer necessary as the various advantages of the direct-current series arc lamp and the alternating-current system of distribution may now be obtained by means of mercury arc rectifiers. By this method alternating current may be used as the supply, as it is readily transformed to direct current for the lamp by means of the rectifiers.

The four-ampere metallic flame arc lamp produces nearly twice as much light as the 6.6 ampere carbon arc lamp. Table I indicates the various component efficiencies for the different apparatus connected with this and other systems. The general outlines of connections and parts of the metallic flame arc lamp* under consideration are shown in Fig. 2.

*See article by Mr. D. A. Bowen in the JOURNAL for May, 1910.

A TYPICAL INSTALLATION OF FOUR-AMPERE METALLIC FLAME ARC LAMPS

One of the towns in which this type of lamp has been adopted is Decatur, Illinois. This town, with a population of about thirty thousand inhabitants, is representative of a large number of medium sized towns. So-called residence districts, with wide well shaded streets, constitute the larger part of the town. It is laid out in an approximately symmetrical manner and thus has fairly regular street intersections. This fact insures satisfactory illumination along practically the entire length of the streets between intersections, with one lamp at each intersection and mounted fairly well above the street surface.

The Old Lighting System—This town has for many years maintained a municipal water and lighting plant. Under the old regime the streets were illuminated by means of 9.6 ampere open arc lamps, power for which was supplied by means of constant-current generators. Eight towers, approximately 130 feet in height, with four arc lamps mounted at the top of each, were used in the center of the town. The idea seems to have prevailed in former years that a very high mounting of lamps in clusters was an advantage as giving a very broad distribution of the light from each cluster. Although the maximum amount of light from the old open arc lamps was in a direction about 45 degrees below the horizontal yet, for a mounting height of 130 feet, the intensity of the illumination on the street surface was so low as to be of little use.

In addition to the eight towers, many of the other important street corners were equipped with single units, but numerous relatively dark places existed throughout the entire community.

Ideas Leading to Improved Conditions—The natural growth of such a community and the resultant branching out into suburbs caused a demand for additional street illumination. The station and equipment were such that it was impossible to make the desired changes without considerably increasing the size of the plant. The alternate scheme was the introduction of a new and improved system. The services of a consulting engineer were secured by the town and of the various types of lamps on the market, the conclusion was reached that the type of lamp having the best qualifications for an installation of this kind was the four-ampere metallic flame arc lamp, current to be supplied by eight mercury arc rectifiers of 100 lights capacity each.

The New Station Equipment—The new station equipment con-

sisted of three 200 kilowatt generators furnishing 2 200 volt, three-phase, 60 cycle current. This particular capacity of generators and their number was chosen in order to provide for future extensions, if necessary. Arrangements were made for parallel operation through the medium of the switchboard shown in Fig. 3. This arrangement resulted in the utmost flexibility and in the greatest ease of operation, while the equipment is comparatively simple. The rectifiers shown in Fig. 4 were installed so that the connections for the different phases and the main bus-bars might be made through the medium of the switchboard shown in Fig. 5. The control devices for the series arc lamp circuits are also mounted on this switchboard.

Each rectifier outfit, consisting essentially of a constant current

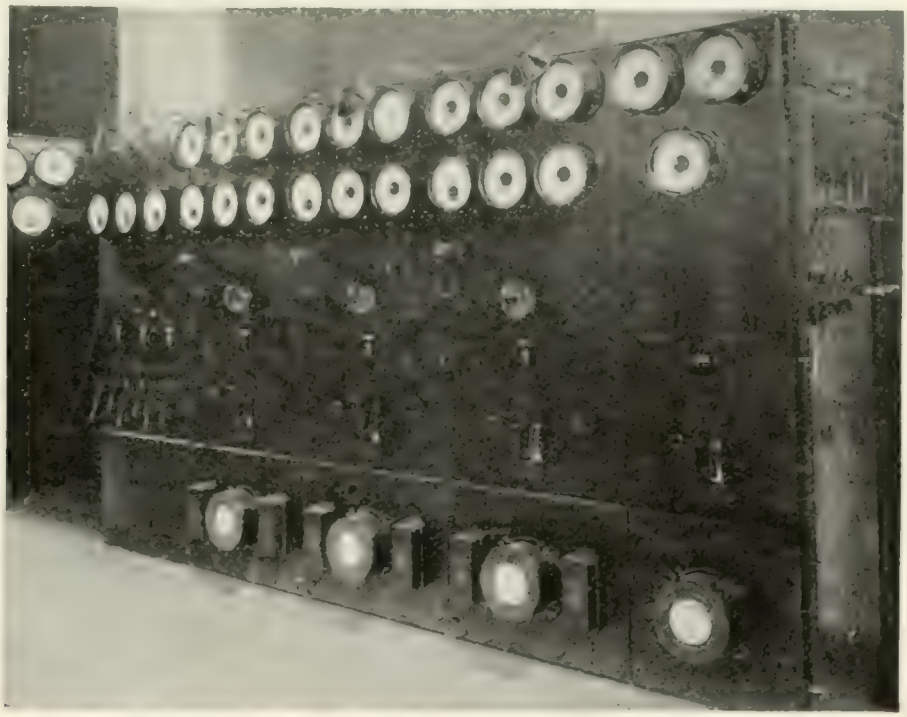


FIG. 3—GENERATOR AND FEEDER PANELS, MUNICIPAL LIGHTING PLANT, DECATUR, ILL.

regulating transformer and rectifier bulb, is mounted in a cylindrical tank as shown in Fig. 6. This transformer has two stationary secondary coils, one at each end of the opening in the core, and two movable primary coils suspended by steel cables so as to move in opposite directions. The primary and secondary circuits are not connected electrically. The rectifier bulb is mounted in a container box and immersed in the oil of the transformer case. The temperature of the bulb is thus maintained at a low point, greatly increasing its life. The container box has contacts so arranged that it can be lifted out through a door in the top of the tank without disconnect-

ing any leads, and is automatically connected again in the circuit when it is lowered along its guides.

The ease of control and simplicity of wiring arrangements of these rectifier outfits make possible their installation in the basement as shown in Fig. 4. Three pairs of leads only are necessary between each rectifier and the switchboard for the operation of two 50-light circuits.

The use of 60 cycle alternating current on the primary side of these rectifiers has an additional advantage in that power is available for commercial lighting and for motors from the same generators which supply the direct-current street lamps.

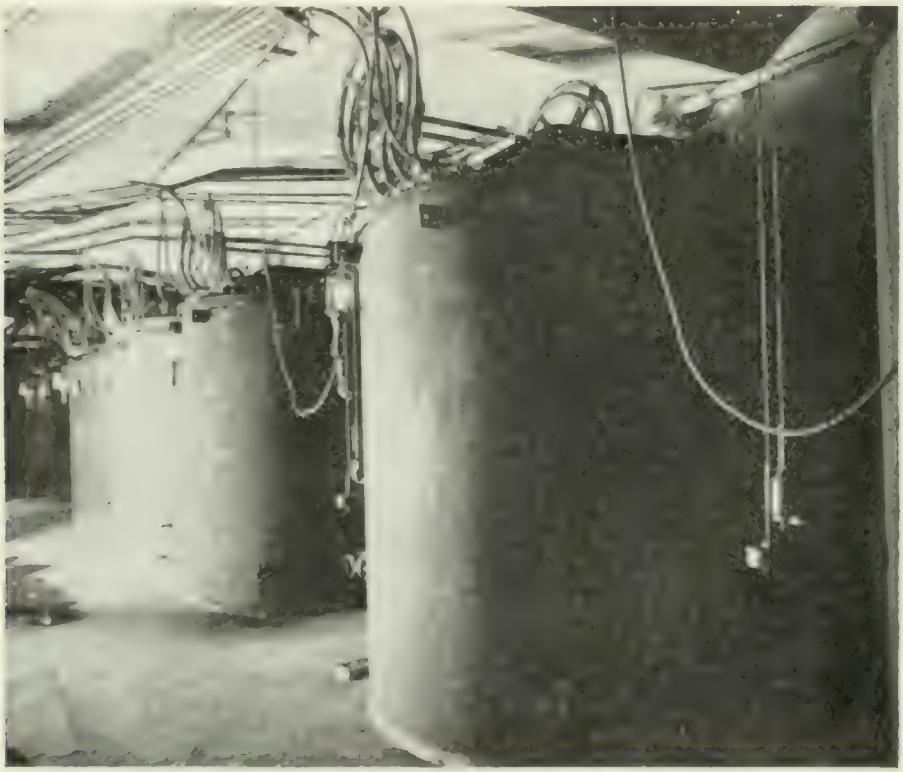


FIG. 4—ONE HUNDRED LAMP MERCURY RECTIFIERS

The rectifiers have been installed in the basement, as they need no attention other than an occasional inspection. All operating and regulating is done at the switchboard.

ITEMS RELATED TO THE NEW SYSTEM

Self-Starting of Rectifiers—In each bulb box of the rectifier outfits is placed a condenser lead with a short piece of cable to which is connected a flexible spring loop. This loop is slipped around the bottom terminals of the bulb in contact with the strips of tinfoil which are connected to the glass bulb. This scheme makes possible what may be termed a semi-self-starting device in that the rectifier

bulb will start up and rectify the current as soon as the proper circuits are closed, provided the oil in which it is immersed is warm enough. The self-starting arrangement, while not absolutely positive, will be found a great convenience in preventing the dropping out of the rectifiers in case of fluctuations or of a momentary failure of the primary voltage. The elimination of the necessity for tilting the bulb when starting is a practical feature which will appeal to the station man.

Operating Features—The installation of this system of metallic flame arc lamps has resulted in satisfaction to the community as well as to the consulting engineers, who have pronounced the system

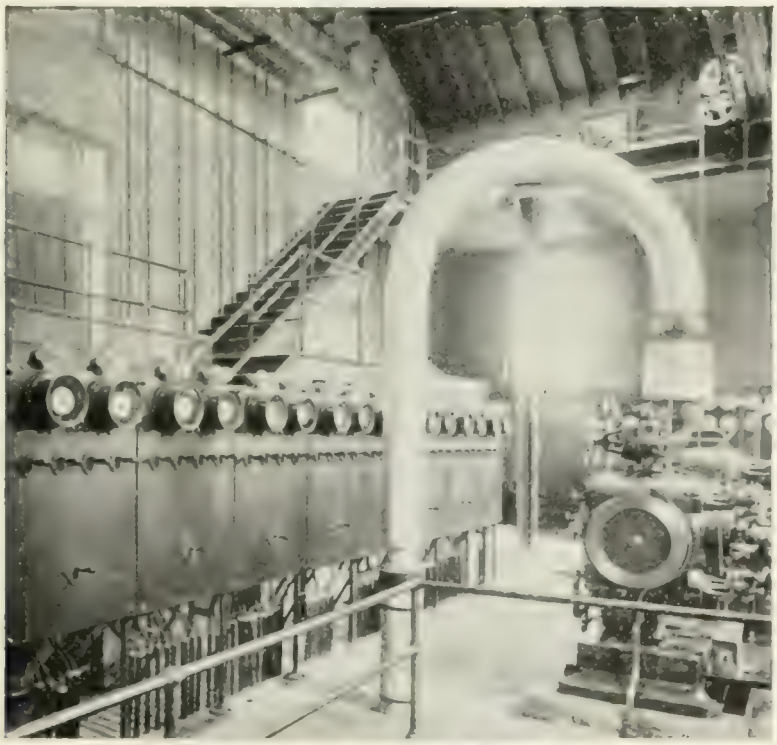


FIG. 5—RECTIFIER PANELS

Eight rectifiers and eight panels are provided, each carrying two 50 ampere circuits.

practically ideal for the conditions. The distribution of light from the lamps has resulted in the largest component of light being effective at a point midway between lamps for the average spacing and mounting height. Recent reports have shown that the total lamp outage does not exceed three-tenths of one percent, on the average. The electrodes used in these lamps have an average burning life of about 300 hours for both electrodes.

In some of the suburban sections of the town, particularly where shade trees are in evidence, tungsten lamps are operated in series with the arc lamps and have given satisfactory results. As previ-

ously described, this introduction of series tungsten lamps in connection with the metallic flame arc lamps adds a flexibility to the system which was not practicable until recently.

The exceptionally long burning life of the electrodes greatly reduces the labor of trimming and an excellent draft arrangement keeps the globes so clean that there is practically no diminution of light due to soot, even during these long periods.

The foregoing items are presented to illustrate the various considerations associated with modern street illumination and particu-

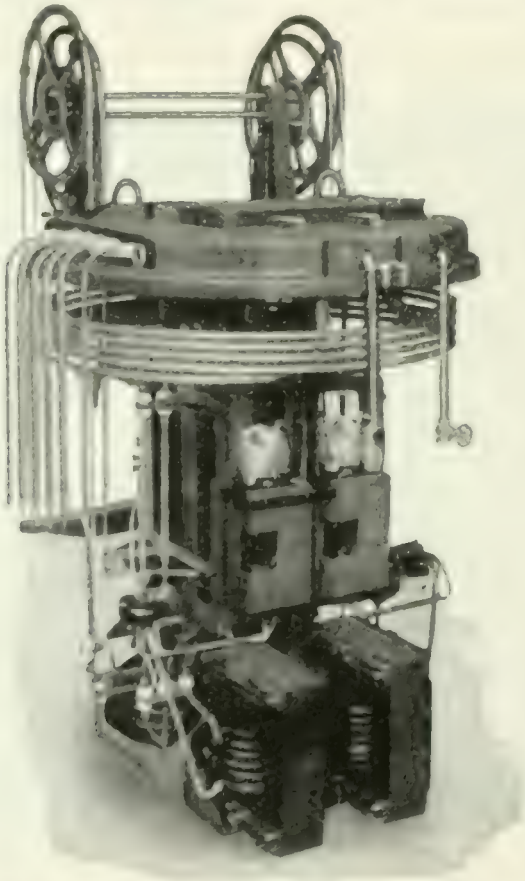


FIG. 6—RECTIFIER OF TEST TANK REMOVED

larly to indicate how these have been met in connection with an actual installation.

It is believed that wherever possible the example of this community in obtaining the services of an expert engineer, may well be followed by other towns confronted with the illumination problem, because such problems should not be considered solely from the standpoint of the commercial cost, but rather from the side of obtaining satisfactory and sufficient illumination for the entire community.

A COMPARISON BETWEEN PORTABLE ELECTRIC DRILLS AND PORTABLE AIR DRILLS

A. G. POPCKE

IN plants where both compressed air and electric power are available the question as to whether to use portable electric or air tools should be given proper consideration. Air drills have been in use longer and in many cases are used without comparing their economy with that of electric drills.

From an economic point of view the electric drill shows the following advantages:—

Transmission of Power—1—The first cost of wiring is less than the first cost of piping. All pipe joints must be carefully made for 80 to 100 pounds gauge pressure.

2—The efficiency of electric transmission is higher than that of air transmission because leakage and pressure losses in air pumps are greater than the losses in electric circuits.

3—Water condensed in air pipes not constantly in use is troublesome.

Flexible Connection from Main Transmission to Drill—1—Wire cable is smaller and more flexible than air hose and, therefore, easier to handle.

2—The first cost and maintenance is greater for air hose than for electric cable.

3—Accidental damage to an electric cable is at once manifested in an open circuit or a short-circuit, whereas damage to an air hose may result in undetected leakage and corresponding decrease in efficiency.

4—A cable can easily be extended without leakage loss. Unions in a hose connection cause increased leakage.

5—Pressure drop in a long air hose is excessive unless large hose is used. The use of hose of large diameter increases the first costs and the cost of maintenance, and such hose is more awkward to handle.

Results of tests made on electric drills are shown in Table I.

TABLE I—POWER REQUIRED TO OPERATE ELECTRIC PORTABLE DRILLS

Size of Drill Inches	Depth Drilled per Minute Inches	Kw Input	Hp Input
3/8	Up to 0.8	0.27 to 0.41	0.36 to 0.55
1/2	Up to 1.5	0.53 to 0.83	0.71 to 1.12
3/4	Up to 1.0	0.5 to 1.23	0.67 to 1.65
1 1/4	Up to 0.5	0.41 to 1.45	0.55 to 1.95

The drills are representative ones of different manufacture; the rate at which holes were drilled in steel, in depth drilled per minute, was varied as indicated in the second column of the table. These conditions caused the variation in power between the limits given.

The amount of power required for air drills is determined from the amount of air required to operate them. Air drills to operate one-half to one inch drills require from 15 to 25 cubic feet of free air per minute while operating from an air line the gauge pressure of which is 90 pounds. The curve in Fig. 3 shows the power required to compress 100 cubic feet of free air per minute with a single stage compressor to the various gauge pressures shown. This curve shows the horse-power at the cylinder and the horse-power at the compressor shaft, assuming a mechanical efficiency of 90 percent for the compressor. Nineteen horse-power is required to compress

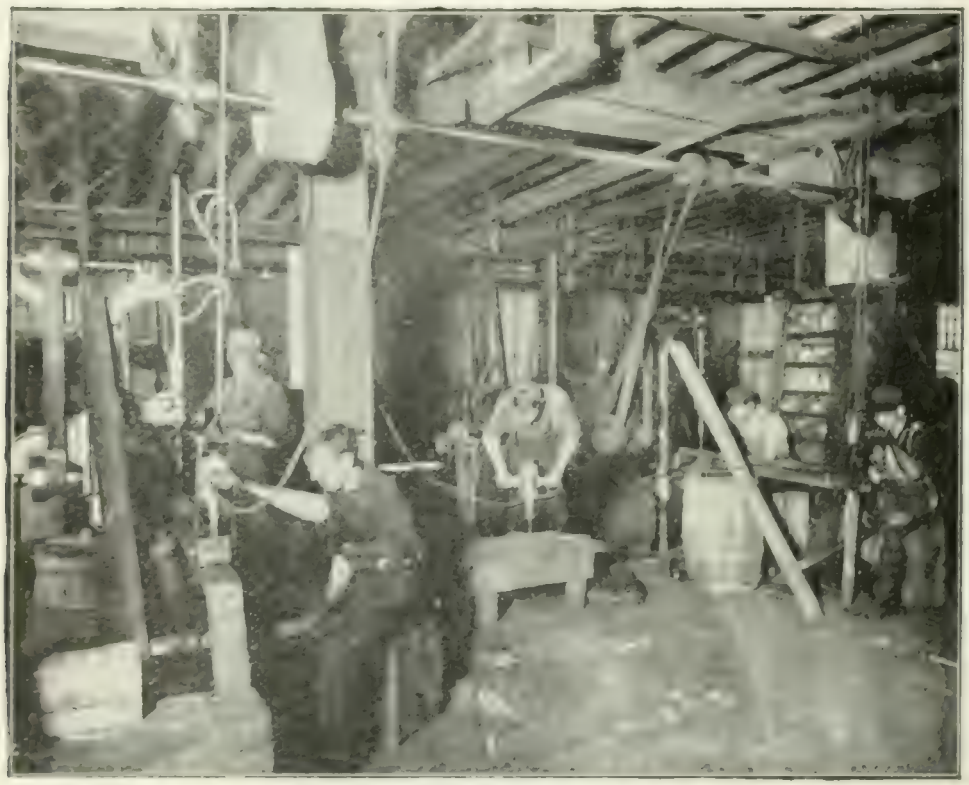


FIG. 1—PORTABLE ELECTRIC DRILLS IN USE IN A REPAIR SHOP

100 pounds of free air to 90 pounds gauge at the compressor shaft; hence to compress 15 to 25 cubic feet of free air per minute requires 2.9 to 4.8 horse-power. As a matter of fact, large transmission losses necessitate very much larger figures to represent the power development at the compressor engine needed to deliver the required amount of air to the drill. The average power required for air drills is thus about 3.5 horse-power while for an electric drill it is 1.1 horse-power. It is safe to say, therefore, that air drills require three times as much power to operate as electric drills.

The construction of the air motors in such small sizes is inefficient and an air motor of this type allows approximately the same flow of air whether it is running idle or doing work. The amount of power taken by an electric drill, on the other hand, is dependent on the work actually done.

THE ECONOMY OF POWER DRILLS

Great economies can be produced by using elecric drills in place of hand drills. Any one who has used an ordinary hand drill knows how easy it is to break a twist drill, due to slight bending, and how much time is lost in removing the broken tool from the hole. Inaccuracies are obtained by the unsteadiness produced when trying to hold the drill in alignment with one hand and supply the necessary power in the form of uniform rotary motion with the other. With an electric drill the rotary torque is uniform and all personal attention can be given to aligning the drill properly. The breakage of drills is reduced to a very low point and the accuracy is increased.

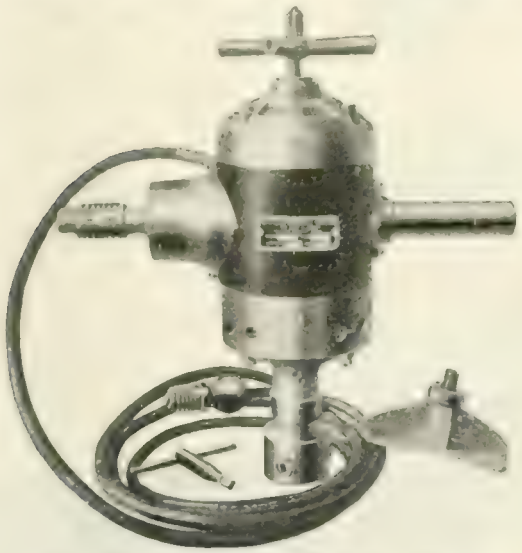


FIG. 2—PORTABLE ELECTRIC DRILL Adapted for screw feed.

TABLE II—TIME REQUIRED TO DRILL ⅜ IN. HOLES WITH A NO. 39 DRILL 0.1″ IN DIAMETER IN CAST IRON.

	Approx. Time per Hole	Approx. Time per 100 Holes	No. of Holes per Hour
By Hand	35 Seconds	60 Min.	100
By Power	5 Seconds	8.5	700

The saving in time when using the power drill is in the ratio of 7 to 1 as indicated in Table I, which is based on time studies in each case.

Electric drills can be used for drilling metal and wood both for manufacturing and repair work. In manufacturing they increase production by saving time when employed in bench work, in erecting and assembling work, in cases where it is easier and more convenient to bring the drill to the work than to take the work to

the drill, and in drilling holes in castings where a drill press would be inaccessible. In repair and maintenance work the applications are unlimited. The electric drills can be used wherever repairing is done, as in garages, small repair shops, hotels, etc.

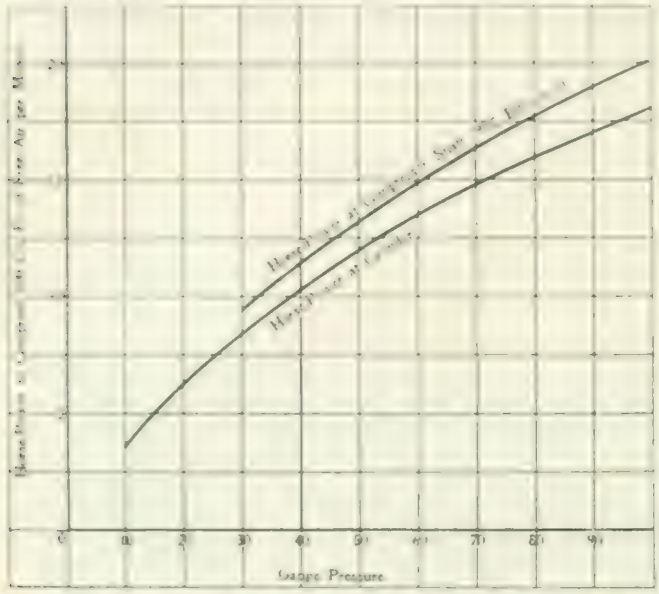


FIG. 3—POWER REQUIRED TO COMPRESS AIR

In remodeling and repairing automobiles there are uses for small electric drills in every stage of the work. New holes are frequently required in the frame, running board, or other parts of the chassis, for the application of the various accessories used in well equipped cars, such as gas tanks, speedometers, tire holders, license plates, tool boxes, trunk racks, etc. Some type of drill is always required for making holes in the frame to apply shock absorbers, or supplemental springs, or in general repair work for drilling out broken bolts, or loose rivets, or in re-locating holes for fenders and such parts. Holes must also be drilled in the wooden body or sills and entering holes made for wood screws used in securing floor boards, foot rest and coat rails. In automobile work it is often necessary to work in cramped and inaccessible places and any one who has been compelled to use hand drills will instantly appreciate the value of electrically-driven tools.

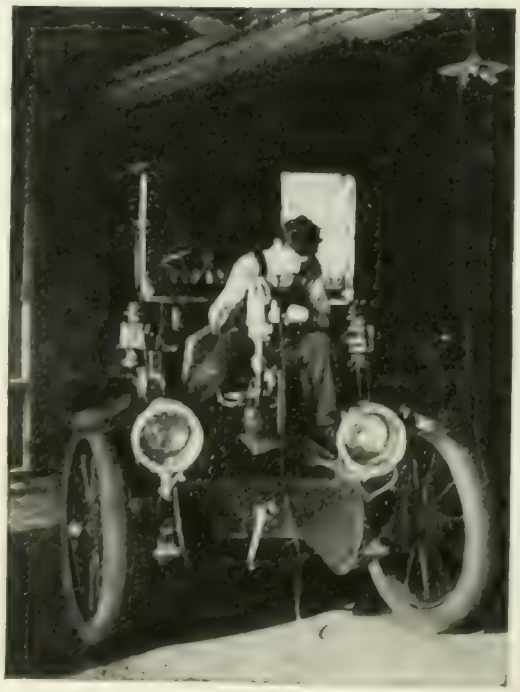


FIG. 4—GRINDING AUTOMOBILE ENGINE VALVES WITH A PORTABLE ELECTRIC DRILL

The portable electric grinders are closely related to the portable drills both in operation and in usefulness. They also can be used in

both manufacturing operations and repair work to replace laborious filing methods, and in all cases where castings are finished.

The convenience of the motor-driven portable tool, and its labor

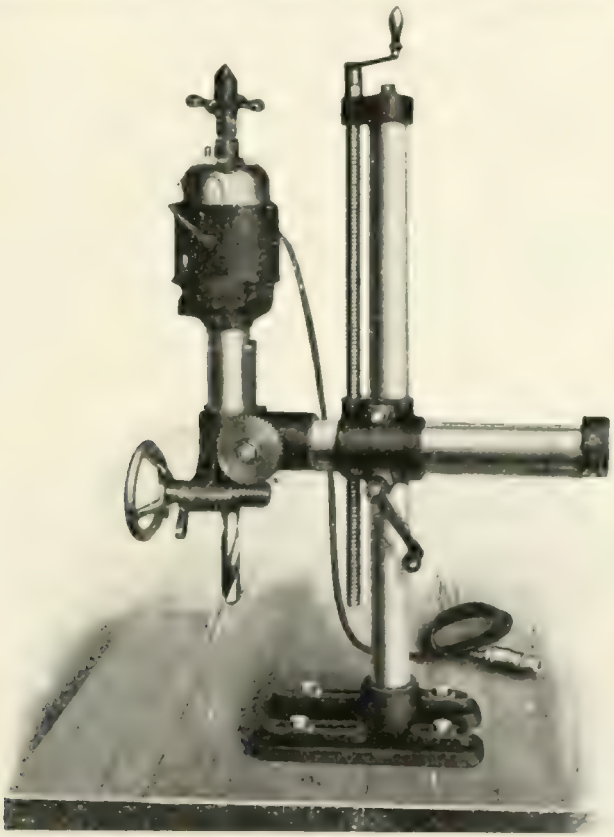


FIG. 5—SMALL MOTOR-DRIVEN RADIAL DRILL

and time saving characteristics form its most attractive feature either for intermittent or steady loads. Its cost of operation is very

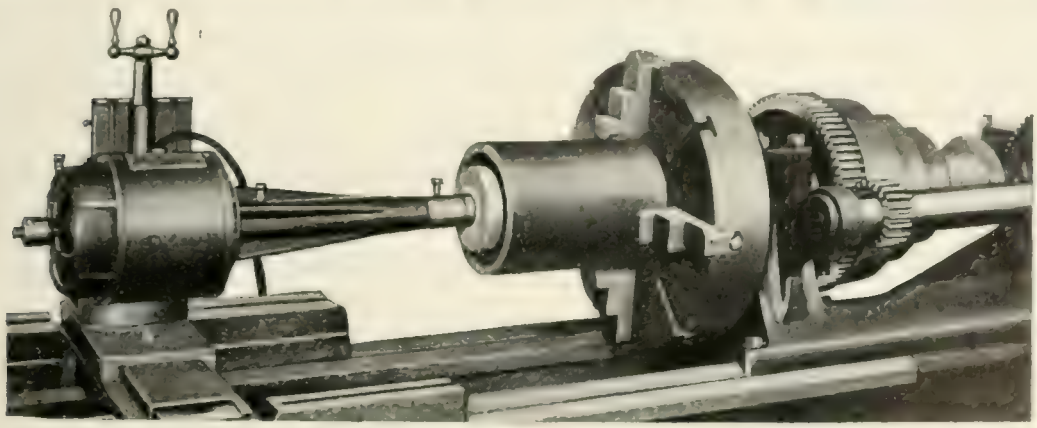


FIG. 6—MOTOR DRIVEN GRINDER FOR INTERNAL CYLINDER AND DIE GRINDING

small. At the same time its great convenience frequently forms an entering wedge to assist in demonstrating to a factory management the many advantages of the use of motors for the larger machinery.

THE PROPER PROCEDURE IN FACTORY ELECTRIFICATION

WILLIAM B. WREAKS

THE correct solution of the power problem is of the utmost importance to all manufacturers. Consideration should be given the question from several points of view, and a system selected that will meet not only the immediate requirements economically but also permit suitable further expansion without undue expense. There are so many factors to be considered, weighed and averaged to obtain the best net results, that the average foreman, superintendent or manager of a factory, who may be fully up-to-date in the line of work for which he is employed, can no more keep properly informed on this specialty and be qualified to assume charge of such work than a layman can properly prepare himself to argue an intricate legal case or do the work of a physician or surgeon.

The two important features to be borne in mind in adopting a system of electric drive are, in the order of their importance, *adaptability* and *economy*. Too often the first, and most important, feature is overlooked in an effort to keep down the initial investment. Yet this is the consideration that requires expert knowledge and practical experience to determine, for each particular industry, the arrangement and equipment best adapted to the requirements of manufacture. The items represented by interest on investment, as well as the cost of maintenance, must of course be added to the cost of producing power to determine the economy of the plant, but it is often false economy to permit this feature to outweigh the proper method of drive, the right application of motors, and the correct selection of type and size of motors to obtain the highest efficiency of production, individually and collectively, from the machines to be driven.

It is the object of the manufacturer to make his product as well as it can be made and then to effect all possible economies in method, system and operation of plant in order to obtain, under these conditions, the highest net profit.

The ideal installation, from the point of view of convenience and flexibility, is the individual driving of machines by their own motors, each motor adapted especially to the requirements of its

machine. This feature can be carried too far, however, resulting in an unwarranted expense for the results accomplished. The work of the industrial engineer is to determine how far to adopt the individual drive method and what machines can be driven in groups and still obtain a method of drive that will produce approximately the desired results. It is thus of importance—first, that the manufacturing conditions and work to be performed be investigated and, second, that a systematic and intelligent analysis of power requirements be made by some one with an expert knowledge of the characteristics of the individual tools and machines, and how they should be operated, before deciding on the system of motor drive to be installed.

ADAPTABILITY

In considering the feature of adaptability proper consideration should be given to the following:

1—The proper grouping of machines to give the best sequence of operations in the different stages of work for the particular articles to be manufactured.

2—The manner in which each tool or machine must be driven to produce the best work most economically, which determines the required speed adjustment and control; the advisability or necessity of independent or individual drive, and the proper torque and speed characteristics of the motor.

3—The position in which tools or machines should be placed to secure good light and convenience of operation and control, so as to obtain the highest efficiency from each operator, this often determining the question of individual drive vs. belt drive from line shaft.

4—The advantage or necessity of rigid transmission of power to the machine, determined by the importance or necessity of uniformity of speed, often making it imperative to drive by individual motor so as to eliminate speed fluctuations, which are impossible to prevent in line shaft drive, with its varying bearing friction and belt slippage, and surging under changes in load.

5—The arrangement of plant, both as to location of machines and selection and application of motors, so as to most readily provide for extensions required by enlargement of the manufacturing plant, increase in facilities of operation or re-arrangement of machines to meet changed conditions or methods of manufacture, this often having an important bearing on the method of drive.

ECONOMY

Having determined upon the most suitable method of electric drive, and the machines that should be driven in groups and those that should be driven by individual motors, it is then necessary to make a careful study of power conditions, so as to select the proper power equipment and the proper motors to give the highest efficiency of operation.

An important factor to be considered is the advisability of purchasing current from a central station, if such current is available and suitable; or the installation of an independent power plant in the factory, and, in the latter case, determination of the size, type and characteristics of generator and of prime mover most suitable to meet the motor requirements. In general it is safe to say that the purchase of power should be given serious consideration, even though it may appear that the power rates quoted would make the cost of power slightly more than the cost to produce it with an independent power plant.

Providing the local power company is equipped with modern and suitable apparatus and a progressive management, offers satisfactory assurance of the continuous delivery of current at a reasonably constant voltage and in sufficient volume to meet the requirements at all times, there are many advantages in purchased power, entirely apart from the question of a saving in power cost, as for instance:—

1—Flexibility of installation, with means always at hand for an increase in power to provide for extensions or to meet temporary demands for increase in production, without having to make any changes except perhaps the installation of one or more additional motors. Frequently the motors already on hand will take care of the increased demand through their overload capacity, while additional demands might readily overload the private power plant to a dangerous extent.

2—If the power requirements are reduced, owing to slack times, or to shutting down part of the factory for any purpose, there need be no reduction in efficiency of operation because of the necessity of keeping an independent plant running to provide an amount of power much below its normal capacity.

3—Power is available at all times, day or night, to provide for overtime operation, without the necessity of keeping up an independent power plant and paying wages for overtime or for any extra fireman or engineer.

4—There is less risk of stoppage or interruption of service from a central station that is properly equipped and well managed, than from an independent plant, due to breakdowns, strikes, or other causes.

5—The factory may be started more quickly, as there is no necessity of getting up steam in boilers or of going through numerous preparatory operations in getting a gas engine plant into commission.

SELECTION OF MOTORS

In making selection of proper motors, the value of experienced expert advice is almost indispensable, as a careful and intelligent series of tests must be made to determine:—

1—The power required to drive each group of machines and each machine which is to be independently driven.

2—The type and characteristics of motor to be used for each class of service.

In determining the power required in an engine-driven plant with line shaft and belt transmission, it is not entirely satisfactory to employ the method frequently adopted, of indicating the engine and cutting off parts of the plant in sequence to obtain the power required for the different groups or individual machines, and then cutting off all machines to obtain the transmission losses, as this method is, at best, inaccurate and does not account for the live load bearing and belt friction losses, which in many plants amount to a considerable percentage of the total losses; nor does it give a record of the time factor in the operation of individual machines; or the variable losses due to changing or intermittent loads; and it does not give the load cycle of machines operating with a periodic load variation, such as punches, presses, planers, etc. The most reliable method of determining power requirements is by a temporary installation of one or more motors to drive the different machines or groups. Tests can then be made which will give curves of power consumption and speed variation, and from this data the size of motor can be accurately and positively determined as well as the speed and torque characteristics, the speed regulation and control, and the proper overload capacity required to operate machines under most efficient conditions for the work to be accomplished.

The selection of suitable motors from this data can be made only from a thorough knowledge of motor design, in order that the motor selected for each machine or group of machines will

have the proper inherent characteristics. Certain classes of machines require, due to their specific load conditions, a form of speed control that can not be efficiently obtained with alternating-current motors, and in such cases they should preferably be driven by direct-current motors, even though the general adoption of an alternating-current system requires the installation of apparatus to convert a portion of the power from alternating to direct-current for this purpose. Other types of machines, while operating at variable speed, will have load characteristics that will permit the use of alternating-current motors with good operating conditions and efficiency. Some machines will require motors with very heavy starting torque, though running under light loads when up to speed, while others will have very light loads at starting but may require motors of large temporary overload capacity.

All of the above and many other operating conditions enter into the problem of determining the proper motors to give the best average or net results, and their proper consideration is vital to the success of the installation. Electric motors will carry overloads beyond their normal capacity, but motors are built to carry overloads of different values, all the way from 25 to 100 percent above rating, and for different periods of duration, and these facts should be considered in making a selection.

THE LONG BURNING FLAME CARBON ARC LAMP

C. E. STEPHENS

THE *open* carbon arc lamp, as employed commercially for general illumination applications, uses plain carbon electrodes, the arc being maintained in the open air. The arc is approximately ⅛ inch long and practically all of the light is emitted from the crater of the carbon points. On account of the fact that the air has free access to the arc chamber, the carbons are consumed very rapidly and frequent renewals are required. The cost of the large number of carbons and labor required in trimming the open arc lamp makes the maintenance cost of this lamp very high.

The old *open carbon arc* lamp was superceded by the *enclosed carbon arc* lamp in which long life of carbons and a comparatively low maintenance cost is secured, along with improved light distribution. The increase in carbon life is secured by enclosing the arc in a glass globe in which the supply of air is restricted.

The *open flame-carbon arc*, with converging carbons, differs from the plain carbon arc in that the light is emitted from the flame instead of from the carbon points. The main body of the electrode is of carbon but certain light producing salts are mixed with a carbon binder and form a central core. These salts enter the arc flame and cause it to become luminous. The use of the light producing salts in the carbon increases the efficiency of the arc very materially. These impregnated carbons are very expensive, however, and when burned in the open air are consumed quite rapidly. The maintenance cost of the *short-life* flame carbon lamp is therefore extremely high.

Numerous attempts were made to increase the life of earlier types of flame carbon arc lamps. These efforts were confined along two lines; first, to consume the carbons in free air and provide sufficient carbon material for long life; second, to enclose the arc. The carbons in most of the short hour lamps are placed in a converging position; that is, both carbons are fed from the top of the lamp and the lower ends come together in a "V" shape to form the arc. This construction makes it necessary to use a carbon of small diameter to make sure that the arc will con-

sume the carbon ends evenly and produce a steady light. Attempts to increase the life by using carbons of greater diameter, resulted in uneven burning of the carbon ends and a very unsteady light. This experience indicated that any increase in life would have to be secured by using longer carbons. Here again, trouble was experienced because the longer carbons required a longer lamp. The principal difficulty however was to produce a long carbon from 8 to 10 millimeters in diameter, with sufficient mechanical strength to permit necessary handling. This was impracticable since the breakage of the long carbons during the manufacturing operation and in shipping, increased the cost to a prohibitive value. Furthermore, the long carbon had a high resistance which affected the regulation of the lamp.



FIG. 1—DIRECT BURNING FLAME CARBON ARC LAMP

The next attempt to secure long life of carbons with the flame lamp, was to use short carbons of small diameter, placing from 6 to 12 carbons in the lamp magazine at each trimming and providing a lamp mechanism suitable for feeding these carbons into the arc in succession. This scheme was unsuccessful because of the complicated lamp mechanism required for performing the feeding operation. Further experiments with a magazine lamp were halted by the remarkable results obtained with an *enclosed* flame carbon arc. Impregnating salts in flame carbons, after being volatilized, pass from the arc and condense as a white powder. Any attempt, therefore, to enclose the arc, involved the use of some scheme to prevent this powder from condensing on the glassware where it would obstruct the light.

A sectional view of the arc and condensing chambers of an enclosed flame arc lamp as illustrated below shows that the arc is enclosed. The amount of air admitted to the enclosure is a minimum. The globe is accurately ground to insure good contact with the globe seat. The upper condensing chamber is of metal, and

on account of its large area exposed to the air, its temperature is comparatively low. The arc chamber is formed by the upper half of the glass globe, and is very hot.

Due to the characteristic shape of the enclosing globe the lower portion is comparatively cool and forms the lower condensing chamber in which the heavier gases will condense. The lighter gases from the arc are carried by air currents into the upper condensing chamber, leaving the section of the globe surrounding the arc very clear. This scheme of condensing the products of combustion in such places as will offer no obstruction to the light rays is a distinctive feature of the lamp and to its effectiveness is due the success of the long burning flame carbon lamp.

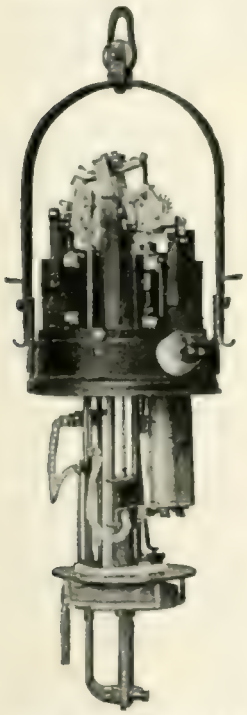


FIG. 2 — MECHANISM OF SERIES ALTERNATING - CURRENT LONG BURNING FLAME CARBON ARC LAMP

The general appearance of a *long burning flame-carbon* arc lamp is shown in Fig. 1, while Fig. 2 shows the internal mechanism of a lamp of the constant current series type. The mechanism is of the focusing type—which maintains the arc in one position throughout the life of the carbons. The feeding and control mechanism of the lamp operates on the differential principle. The upper carbon holder is connected to the lower carbon side rod by a flexible chain which passes over a chain-wheel in a rocker arm. With no current on the lamp, the carbons come together by gravity. When current is turned on the series coil strikes the arc by actuating the rocker arm; the shunt coil is connected across the arc and opposes the pull of the series coil on the rocker arm. The movement of the rocker arm rotates the chain wheel and regulates the arc length. As the carbons are consumed the floating movement of the rocker arm trips a release

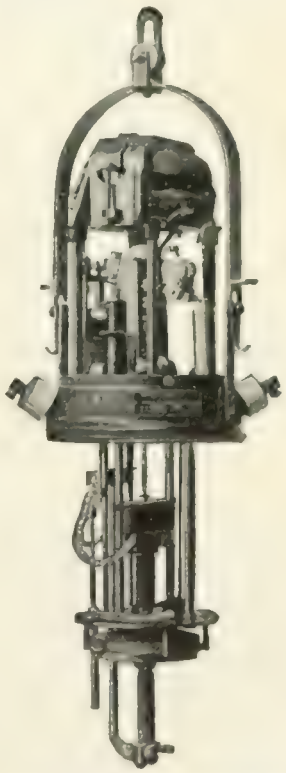


FIG. 3—MECHANISM OF MULTIPLE ALTERNATING - CURRENT LONG BURNING FLAME CARBON ARC LAMP

cam on the chain wheel and permits the carbons to approach each other and feed together. This scheme is known as the "sneak" feed. Feeding of the carbons does not cause the light to flicker, as is the case in a lamp using a clutch. The carbons are fed into the arc at the same rate, the upper carbon being made larger in diameter than the lower one to neutralize its naturally faster burning rate and to secure a steadier arc by preventing the flame from running up the side of the upper carbon.

Instead of having an impregnated core, the entire carbons are impregnated with a salt, which supplies the luminous characteristic of the arc. This salt is thoroughly mixed with the carbon particles and a homogeneous mixture is secured. Considerable development work has been necessary to produce a suitable carbon for the flame arc lamp. The conditions to be met are that the light must be steady, without objectionable flicker, of uniform color and brilliancy, and with a life of not less than 100 hours. It is necessary to provide a sufficient proportion of salt to maintain the volume of light at a satisfactory value and to mix this light giving salt thoroughly with the carbon base to form a homogeneous mass. Too great a proportion of the luminous salt, however, increases the possibility of the formation of an insulating slag when the carbons are cold. This insulating slag causes the lamp to fail to start when current is turned on. Carbons can be secured that will give from 2 500 to 3 000 maximum candle-power. It would probably be better practice to use a carbon giving slightly lower candle-power values, which will be free from insulating slag conditions and insure reliable and successful service. To insure reliability of service, the carbons used are those giving a compromise between volume of light, life and reliability of operation. The dimensions of the upper carbon are 0.79 by 10 inches (20 by 250 millimeters), and of the lower carbon 0.71 by 8.5 inches (18 by 220 millimeters). Carbons producing either a yellow or

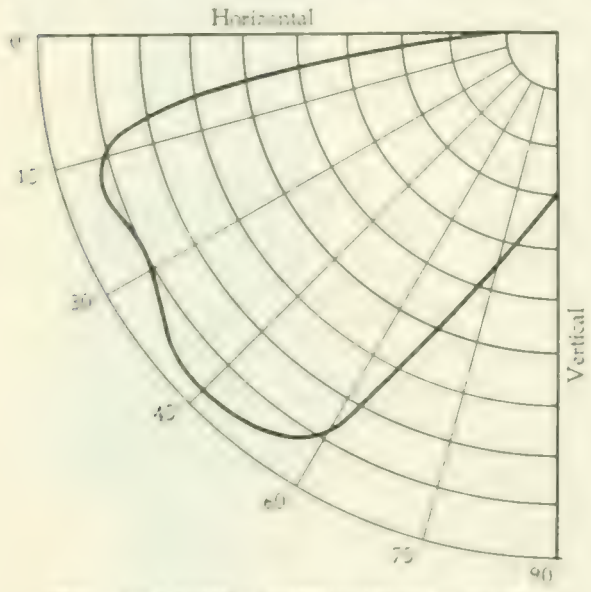


FIG. 4—LIGHT DISTRIBUTION CURVE.

white light can be used. Their dimensions are such that they can be handled with reasonable care without breakage.

The design of the long-burning, flame arc lamp, is exceedingly flexible. With only slight modification, the lamp can be arranged to operate on standard commercial circuits of any voltage, whether alternating or direct current. It is a particularly desirable feature of lamp design, to have as many parts as possible common to the entire line.

The multiple alternating current flame carbon arc lamp has the same general features of design as the series lamp, viz., focusing arc, sneak feed, condensing scheme, carbons, arrangements of carbons, etc. The mechanism is of the rocker arm type as is used in the series lamp except the shunt coil, cut-out, etc., are omitted. The

TABLE I—DATA ON FLAME CARBON ARC LAMPS

Type of Lamp	Amp. at Terminals	Amp. at Arc	Volts at Terminals	Electrical Eff.—Percent	Power-Factor—Percent	Net Wt. with Globe—Lbs.	Overall Length—Inches	Upper Carbon, Size in Inches	Lower Carbon, Size in Inches
Series A.C.....	10	10	50	94	85	49	36.75	0.79x10	0.71x8.5
Mult. A.C.....	6	10	110	88	65	65	38.75	0.79x10	0.71x8.5
Mult. D.C.....	6.6	6.6	110	63.6	...	49	36.75	0.79x10	0.63x8
Series D.C.....	10	10	52	94	...	49	36.75	0.79x10	0.63x8
Series-Multiple D.C....	10	10	55	73	...	49	36.75	0.79x10	0.63x8

arc operates at 10 amperes, 43 volts. An auto-transformer is mounted in the top of the lamp and serves to change the line voltage from 110 volts to that required by the arc. The secondary voltage regulation of the auto-transformer has a drooping characteristic which provides the necessary "ballast" for the arc thus eliminating the usual resistance for this purpose. This feature is particularly desirable since it makes it possible to take advantage of the superior efficiency of the flame carbon when operated at a comparatively high current value. For a given energy consumption, of say 500 watts, a greater efficiency and a steadier arc will be secured from a 10 ampere, 50 volt arc than from a 7 ampere, 72 volt arc.

A typical curve of light distribution for the long life flame carbon arc lamp with carbons arranged vertically is shown in Fig. 4. This curve shows the characteristic distribution of the lamp in

a vertical plane. Certain conditions of installation such as spacing, mounting height, etc., make it desirable to increase or decrease the amount of light emitted at the various angles, to obtain the highest illuminating efficiency. This distribution is easily secured by the use of suitable reflectors to adapt the lamp for these various applications. The luminous flame, being in a vertical position, gives a maximum candle-power from 30 to 40 degrees below horizontal and rapidly decreasing candle-power values above and below these angles. This characteristic distribution of light makes this lamp particularly adapted for the illumination of large areas. The luminous efficiency of the lamp varies from 0.25 to 0.40 watts per mean lower hemispherical candle-power, depending upon the carbon used.

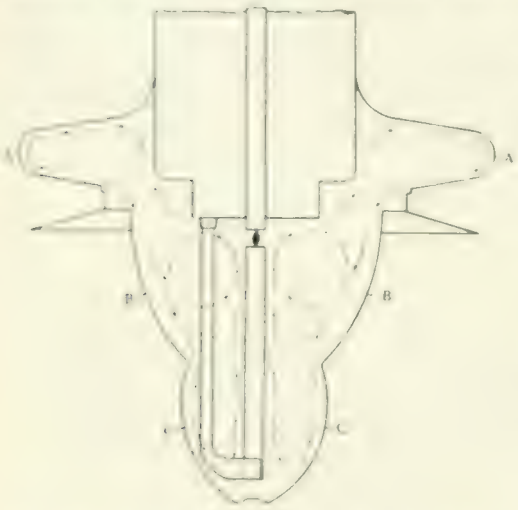


FIG. 5—DRAFT SCHEME OF ENCLOSED FLAME CARBON ARC LAMP.

aa—Condenser. *bb*—Arc Chamber. *cc*—Lower Condenser. The heat prevents the gases from condensing on the glass at *bb*. The long arrow points show how the lighter gases are carried by the air currents into the upper condensing chamber. The short arrows show how the heavier gases circulate into the lower section of the globe and condense, leaving the section of the globe surrounding the arc unobstructed.

The series design is used largely for street illumination, and other areas where series circuits are permitted. The alternating-current series lamps are operated from the secondary of a constant current regulating transformer. These transformers are made in 6, 12, 25, 35, 50, 75 and 100 light sizes, with an average efficiency of about 95 percent for the various sizes. The electrical efficiency of the lamp is 94 percent, and the efficiency of the entire series system from bus-bar to arc, including line loss, is approximately 90 percent.

The multiple lamps, both alternating and direct-current, are used largely for mills, factories, docks, railroad yards, display lighting, etc., having a general application wherever the short life flame carbon lamp is installed.

The general features of this type of lamp which are worthy of special notice are the high luminous efficiency of the lamp; the comparatively low maintenance cost for a flame carbon lamp; the superior distribution of light for large areas, and the flexibility

of design which adapts the lamp for operation on standard voltages of commercial circuits, both alternating and direct-current. This

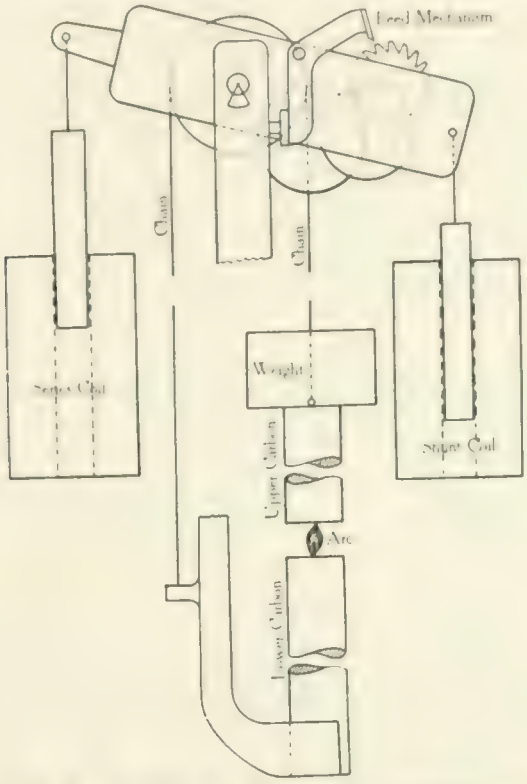


FIG. 6—DIAGRAM SHOWING PRINCIPLE OF SNEAK FEED MECHANISM.

type of lamp is deserving of special consideration in extensions and particularly in improved lighting propositions for street and industrial illumination.

GEAR DATA FOR MOTOR APPLICATIONS

C. W. DRAKE

IN the selection or specification of pinions for motors in geared applications, three dimensions must be determined; namely, the face, diameter and pitch. These dimensions vary symmetrically according to the strength required, or, in other words, according to the torque exerted in transmitting power. As the horse-power and speed of the motor in any case determine the torque, it is evident these are the factors determining the proper dimensions of a pinion for the motor. A line of pinions with dimensions increasing symmetrically with the torque will therefore answer the purpose for all combinations of horse-power and speed. Every geared application requires special consideration, since the nature of the service, the shaft diameter, etc., may affect the dimensions of the pinion.

The dimensions for pinions for average conditions of service are given in Fig. 1. This chart is useful in making preliminary estimates or selections of pinions for geared motors. The chart applies without correction *to steel pinions only*. The diameters are considered about standard for the various ratings, although both smaller and larger pinions can generally be used, the limiting size for small pinions being the strength and number of teeth, and, for large pinions, the pitch line speed.

For example, to determine the steel pinion for a five horse-power motor at 1 200 r.p.m., find the intersection of the oblique line marked *5 Hp* with the horizontal line through *1 200 r.p.m.* On the vertical line through this intersection may be found *21.9 pounds torque, 2.3 inches pinion face, 3.2 inches pitch diameter*, and a diametral pitch of *1.55*. A 2.25 in. pinion face is good practice here, since pinion face dimensions with fractions smaller than 0.25 in. are not commonly used. The diametral pitch is also usually a whole number, except for very large pinions, where half pitches are sometimes used, so that a pitch of 5 would probably be used in the above case. Since the number of teeth is the product of the pitch diameter and the diametral pitch, the assumed pitch diameter, *3.2* in., is satisfactory with the 5 pitch, because it gives a whole number of teeth; that is, *16*.

In gear drive the pinion is subject to most rapid wear owing to its smaller diameter. It is as important to have a pinion of good wearing qualities as it is to have one of sufficient strength and for a pinion of a given material, the ability to withstand wear depends

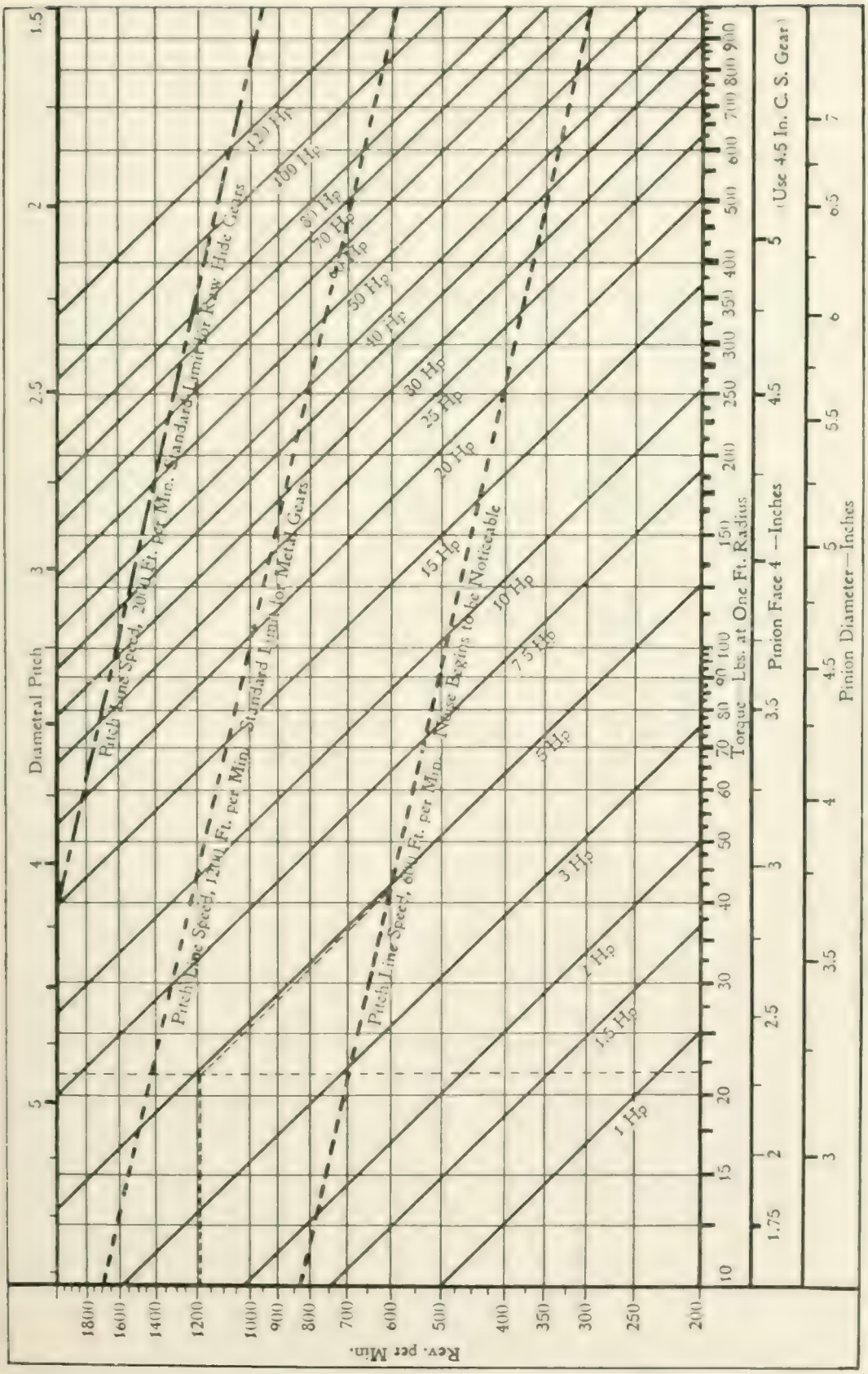


FIG. 1.—CHART FOR DETERMINING APPROXIMATE COMMERCIAL VALUES OF PINION DIAMETER, PINION FACE, DIAMETRAL PITCH, PITCH LINE SPEED, AND TORQUE, WITH REVOLUTIONS PER MINUTE AND HORSE POWER OF MOTOR GIVEN

mainly, if not wholly, on the width of the face. With a steel pinion and a cast iron gear the former is usually the limiting factor of life and the latter the limiting factor of strength.

Cast steel gears are about twice as strong as cast iron, and should be used when the face of a corresponding cast iron gear would be 4.5 inches or more, although the cost is approximately double that of cast iron. With continuous contact all along the length of the teeth, the strength of the gear is approximately proportional to the face and the square of the circular pitch, but gear teeth seldom make such contact until worn down in service. With new gears the whole pressure is brought to bear on the high spots, and stripping may occur before they are worn down; hence the necessity of using the stronger material.

NOISE AND PITCH LINE SPEED LIMITS

Spur gears ordinarily begin to make a noticeable noise at pitch line speeds of about 600 feet per minute, but under average conditions may not become disagreeably noisy with pitch line speeds under 1 200 feet per minute. The amount of noise allowable depends on the noise made by surrounding machinery, on the character of the workmen, and on the nature of the work in the vicinity. A noise that would be unnoticeable in a boiler shop might be exceedingly disagreeable in a shop that was otherwise comparatively quiet. Where noise is not a limiting feature there is no limit to allowable pitch line speeds, except the increased wear and depreciation of the motor, gears and driven machine; but depreciation may become a very important factor with high pitch line speeds, say 2 500 feet per minute, or sometimes even less. Tests recently made to determine a design for gears that will give the least noise and yet have sufficient strength and wearing qualities, indicate the following facts, other conditions being the same:

1—Gears having large teeth give forth a relatively greater volume of noise at a low pitch that does not carry far, while gears having smaller teeth give forth a smaller volume of noise at a higher pitch that carries farther.

2—Most of the noise comes from the gear, and not from the pinion or the motor.

3—A gear designed so that it will give a dead sound when struck a blow with a hammer will be the least noisy in operation.

BRONZE AND RAW HIDE PINIONS

For equal strength the working face of raw hide pinions must be about 25 percent wider than corresponding steel pinions. For

quiet operation, only the raw hide should be in contact with the gear, although for high torque motors and for other severe service the gears may be widened to cover the entire pinion, thus making use of the metal flanges. Where steel pinions would make objectionable noise, raw hide pinions should be used if the stresses permit, since the pitch line speed with a raw hide pinion is limited more by the rapid wear of the pinion than by noise. A pitch line speed of 2 000 feet per minute is considered a fair average limit for raw hide, but 2 500 to 3 000 feet per minute may be used under especially favorable conditions regarding attendance, lubrication, absence of moisture or high temperature, for intermittent service, or where the life of the pinion is not important.

The wear and noise of bronze pinions are intermediate between those of raw hide and steel. Bronze pinions are particularly adapted to conditions where heat and moisture prohibit the use of raw hide. Their cost is about the same as raw hide.

CONDITIONS FOR NOISELESS OPERATION

Rigid and massive supports and close fitting bearings for both the motor and the driven machine are conducive to a noiseless gear drive, and the pinion should always be placed close to the motor bearing. A gear application with motor mounted upon the ceiling might be twice as noisy as the same application with motor mounted on a concrete foundation.

PINIONS FOR HIGH TORQUE MOTORS

For series motors and those heavily compounded, as bending roll motors, or for motors subject to very severe service of any kind, select a pinion suitable for a constant speed motor of the same rated r.p.m., but of about 50 percent higher horse-power.

SELECTION OF RATIO FOR BACK GEARED MOTORS

A ratio of about 6 to 1 is usually standard for back geared motors, and should be selected wherever possible, but smaller ratios down to 3 to 1 or maximum ratios up to 7 to 1 may be obtained in certain capacities of motors for service where the conditions of the application warrant the use of such ratios.

OUTBOARD BEARINGS

Outboard bearings should be used for geared motors of about 40 horse-power and above in heavy geared service requiring con-

tinuous operation with frequent reversing and overloads; also for all motors of about 100 horse-power and above in any geared service.

The proper use of outboard bearings cannot be emphasized too strongly, since on account of increased expense there is a tendency to omit them even where good engineering demands their use. It should be remembered that the best service is invariably the cheapest in the end.

DEFINITIONS AND FORMULAS

A *circle* whose circumference passes through the point of contact on each tooth of a gear or pinion when this point is on the line connecting the centers of the two wheels is called the *pitch circle*. The diameter of this circle is the *pitch diameter* and its circumference is the *pitch line*.

Diameter, when applied to gears, is always understood to mean the pitch diameter.

Diametral Pitch is the number of teeth to each inch of the pitch diameter. To illustrate: If a pinion has 18 teeth and the pitch diameter is 3 inches, there are 6 teeth to each inch of the pitch diameter and the diametral pitch is 6.

Circular Pitch is the distance from the center of one tooth to the center of the next, measured along the pitch line.

In the following formulas, for use in gear problems:—

d^1 = Pitch diameter of pinion
d = Outside diameter of pinion
p = Circular pitch
p^1 = Diametral pitch
S = Distance between centers $= \frac{1}{2}(D^1 + d^1)$

D^1 = Pitch diameter of gear
D = Outside diameter of gear
n = Number of teeth on pinion
N = Number of teeth on gear
r = Gear ratio $= \frac{N}{n} = \frac{D^1}{d^1} = \frac{D}{d}$

$$p = \frac{\pi}{p^1} = \frac{\pi d}{n+2} \quad \ldots\ldots (1) \qquad d = \frac{2S}{r+1} \quad \ldots\ldots (6)$$

$$p^1 = \frac{\pi}{p} = \frac{n-2}{d} \quad \ldots\ldots (2) \qquad D^1 = \frac{2Sr}{r+1} \quad \ldots\ldots (7)$$

$$n = d(p^1) = \frac{\pi d}{p} = (p)(p^1) = 2 \quad \ldots\ldots (3) \qquad n = \frac{2Sp^1}{r+1} \quad \ldots\ldots (8)$$

$$p = \frac{\pi}{p^1} \quad \ldots\ldots (4) \qquad N = \frac{2Sp^1 r}{r+1} \quad \ldots\ldots (9)$$

$$S = \frac{p^1 + n}{2p^1} \quad \ldots\ldots (5) \qquad S = \frac{d(r+1)}{2} \quad \ldots\ldots (10)$$

DEVELOPMENT IN THE TUNGSTEN LAMP

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DURING the past year or more the quality of the tungsten lamp has been consistently and uniformly improved, both from a manufacturing and from a lamp engineering standpoint. From the manufacturing standpoint the improvement consisted in the raising of the average quality of the lamps manufactured, due to the standardization of factory processes and increased experience of the operators. From the lamp engineering standpoint the improvement was due to an exhaustive scientific and practical study of the constructional details of the lamp and of the proper relations of the various component parts.

The ordinary user of tungsten lamps cannot realize how many different points have to be taken into consideration in the manufacture of such a lamp. The average life of a tungsten lamp depends not only upon the filament, though that is, of course, of paramount importance, but also on a number of other factors which can affect its quality deleteriously, if they have not been properly taken care of during the manufacture. One of the most important of these factors is the choice of the proper material to be used for the anchors, which hold the tungsten filament in position. No less important is the determination of the proper cross-section of the anchor material in its relation to the diameter of the filament in the various types of tungsten lamps.

The tungsten filament in a lamp burning at normal efficiency is heated up to an extremely high temperature, which is estimated at about 2 300 degrees C. This temperature is very considerably higher than the melting point of the majority of the metals which commercially come into consideration as materials to be used for the anchors. It is therefore necessary to make the anchors of such a cross-section that they will not be overheated at the point where the filament touches them. This will invariably happen if the cross-section of the anchor material is too small and, as a consequence, the metal of which the anchor consists will be vaporized, and the vapor will deposit upon the inner surface of the lamp bulb and blacken it. Furthermore, it is easily possible for the filament to stick to the anchor, and then when the lamp is turned off, the filament may break, because it has not sufficient leeway to contract. In the early

types of tungsten lamps it happened quite frequently that the lamps did not give satisfaction and blackened on account of the anchor material.

On the other hand, if the cross-section of the anchor is too large, it will exert too much of a cooling action on the filament itself, and a comparatively large amount of filament will not be incandescent, and that part of it which is incandescent will be strained considerably more than it should be.

Another problem presented itself when it was found that the gases occluded in the metals, which could be used as anchors, played a not unimportant role. It is of course well known in general, that all commercial metals contain a certain amount of occluded gases, but for the greater part of the uses to which these metals are put, this phenomenon is not of much importance. The case is different, however, with a tungsten lamp, which has to be evacuated to a very high degree, and it is very important that this vacuum be maintained unimpaired during the life of the lamp. As the gases occluded in the anchor metal are given off very gradually, and to that extent impair the vacuum, it was, of course, important to choose metals which contain a minimum amount of occluded gases.

From these brief remarks it can immediately be realized what a large amount of research work, on the part of the lamp makers, was necessary to obtain the proper material for these anchors and to establish their proper dimensions. These are different, of course, for each type of lamp, because each type has a different filament diameter, and the cross-section of the anchors must bear a certain proportion to the diameter of the filament. The problem was especially difficult in those types of lamps which have a filament with a rather large diameter, for instance, the 250, 400 and 500 watt types, and also the street series types. It might also be safe to say that perhaps the greatly predominating cause for the former unsatisfactory performance of the street series types of lamps was due to the improper material or dimensions of the anchors and lead-in wires.

Another very important question, especially in the larger lamps, was the proper joining of the filaments to the lead-in wires, with a view of obtaining a large enough joint, and one which would properly envelop the filament and yet not be so large as to cool the filament too much. This has been done very satisfactorily in Westinghouse lamps by the introduction of the wrapped and fused joint, which provide at the same time a sufficient flexibility of the

filament at the joint and an absolutely rigid connection between the filament and the lead-in wires.

Hand-in-hand with the development of these large types of lamps went the development of lamps of very small sizes, in the 110 volt range, of the sizes below 25 watt and the development of the 220 volt types. In the small wattage lamps of standard voltages the principal difficulty resided in the manufacture of the filament itself. When it is considered that, for instance, the 110 volt, 10 watt tungsten lamp has a filament, the diameter of which is only 0.0006 inch, and which can hardly be seen by the operators in the manufacture of the lamp, it can easily be understood that considerable difficulties had to be overcome before a filament of that thinness could even be manufactured, especially as, in order to prevent the production of off-voltage lamps, the diameter of the filament has to be very exact and uniform. It was an exceedingly difficult thing for the manufacturers of diamond dies to produce dies of that small diameter which were sufficiently round for the manufacture of the filament. However, it was only a question of time before the lamp factories were able to produce a filament of such small diameter, and it is only a question of getting the operators in the factory sufficiently skilled before lamps of such low wattages can be successfully made on a large scale and placed on the market. The question of the proper anchoring of these extremely thin filaments was also of great importance, though perhaps not of so much difficulty as that of anchoring the lamps with large filaments.

There is still another class of lamps in which much advance has been made during the past year or more, and that is the tungsten sign lamp. Owing to the improvements which have been made in the manufacture of this lamp, and due largely to the ruggedness of the filament and the proper proportioning of the lamp parts, this lamp is now a very satisfactory commercial article. It may be of interest to note in this connection that, during the past year, there has been an increase of 75 to 80 percent in the tungsten sign lamp business of the company with which the writer is connected, and it is confidently expected that it will increase still further.

The high efficiency of the tungsten lamp certainly makes it the proper lamp to be used for sign lighting purposes, and the fact that the business has increased in such proportion shows that the buying public realizes this fact. One of the latest developments, which has reference to the sign lighting business, is the endeavor to produce a five watt, 55 volt tungsten sign lamp, two lamps burning in series

on a 110 volt circuit. This type of lamp will largely do away with the annoyances experienced in burning a number of low voltage sign lamps in series, due to the fact that if one of the lamps in a series burned out, the rest of them went out also.

Another type of lamp, the use of which has largely increased, and is continually increasing, is the six volt tungsten automobile lamp. Owing to the improvements in the manufacture which have entirely overcome the former drawbacks, and especially that of the brittleness of the filament, this lamp is now fully equal mechanically to the carbon lamp, and of course, much more economical in current consumption.

In general, the improvements in the manufacture of tungsten lamps of all types have resulted in a gradual increasing of the efficiency. For instance, the rating of the principal 110 volt types is now as follows:—

15, 20 and 25 watt,	110 volt type,	1.31	watts	per	mean	horizontal	candle		
40 watt,	"	"	"	1.23	"	"	"	"	"
60, 100 and 150 watt,	"	"	"	1.18	"	"	"	"	"
250, 400 and 500 watt,	"	"	"	1.13	"	"	"	"	"

It is hoped that future improvements will result in still further increasing these efficiencies, while at the same time maintaining the average performance, that is the test life period in hours with 20 percent drop in candle-power at the end of 1 000 hours.

When these figures are compared with the ratings and performance of tungsten lamps a few years ago, the great progress made in the art of lamp manufacture can at once be realized. Though it can no longer be said that the art of making tungsten lamps is in its infancy, yet there still remains a great deal to be done in the future improvement and standardization of manufacturing operations of this lamp, and to this task the lamp factories are bending every energy and devoting a considerable amount of engineering research. As the price of tungsten lamps has been steadily decreasing, their field of usefulness has correspondingly grown and will continue to grow in the future.

THEORY OF THE OPERATION OF MERCURY RECTIFIERS*

R. P. JACKSON

THE development and distribution of electric power is very largely by alternating current. There are some purposes, however, for which direct current is either necessary or much to be preferred. Among these are the charging of storage batteries and the operation of arc lamps. In order to draw power from an established distributing system for any of these purposes, it is necessary to use some device that will take power in the alternating-current form and deliver it in the form desired. For this purpose the mercury rectifier has come into general use. This device consists of a vacuum chamber with two anodes which are commonly of graphite or iron, and a cathode which, in the practical rectifier, is mercury, although some other metals of low boiling point would operate. There is usually an auxiliary anode of mercury used only for producing an initial starting arc. The common connections used in battery charging are indicated in Fig. 1. For one to whom the flow of current is a little mysterious, the hydraulic analogy indicated in Fig. 2 will be helpful. The rectifier is essentially a check valve in which pulsations are so guided as to produce a unidirectional flow. No extended description of the operation of such a mechanism is necessary.

The mercury rectifier works in exactly the same way after the current flow is once started in the mercury vapor in the vacuum chamber, providing the mercury pool is the cathode or negative. Current will flow from an anode to the mercury but will not flow from any point to an anode or positive terminal. As a matter of fact current, in any appreciable quantity, will not flow in any direction whatever until, by some special means, a spark or small arc has been produced at the surface of the mercury in such a direction that the cathode mercury pool is at the negative end of the arc. The reason for this will be discussed later under the theory of operation.

The direct current secured from a single-phase rectifier is not uniform but is undulating or possesses a "ripple." This ripple is the result of the combining of the two half waves of the alternating current, with a partial bridging-over of the low point between them. This bridging-over is secured by the use of a reactance coil, which

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absorbs energy during the rise of the wave and gives it out while the wave is falling in value. This external reactance can be omitted and the same result obtained by means of leakage between the two halves of the transformers in the supply circuit.

While rectifiers are commonly used only on single-phase circuits, it is entirely possible to build a rectifier with three anodes to take its supply from a three-phase circuit and deliver direct current. In this case the undulation or ripple in the direct current will be much reduced, inasmuch as there will be six half wave peaks instead of two in the period of one complete wave.

As the voltage drop through the rectifier bulb or tube is approximately fixed and ranges from 14 volts for a battery charging or low voltage bulb to 25 volts for an arc light or high voltage bulb, the resulting efficiency depends largely on the voltage of the direct-current circuit to which power is delivered. It is obvious that on a 14 volt direct-current circuit with 14 volts drop in the bulb the efficiency cannot be above 50 percent. On the other hand, when delivering 110 volts direct current, the efficiency may be 80 percent or over, and on arc light outfits delivering, say, 3500 volts, the bulb drop has no appreciable effect and the efficiency of the regulating transformer is the determining factor. This may reach 90 to 92 percent.

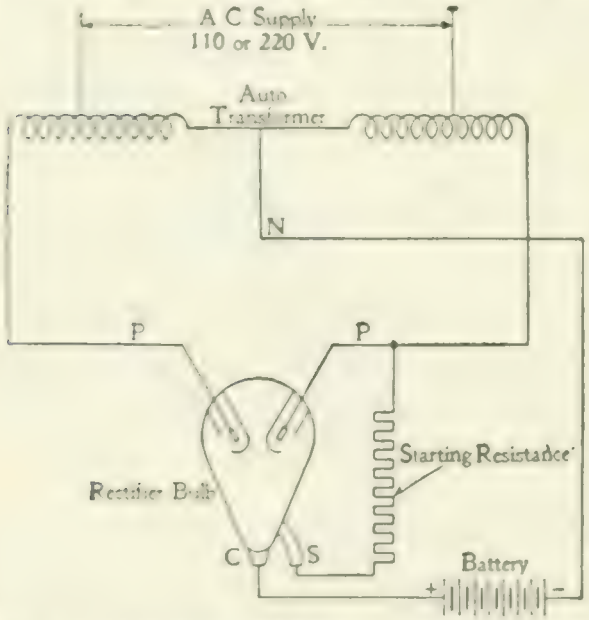


FIG. 1—COOPER-HEWITT MERCURY RECTIFIER CONNECTIONS USED IN BATTERY CHARGING

There seems to be no fundamental reason why the mercury rectifier cannot be built for any desired capacity. The technical difficulties, however, of producing and maintaining vacuum apparatus of large size in such perfect condition as to be reasonably free from trouble are very great. While this is true, there is no other device that can accomplish the same result with the same simplicity and cheapness, and for that reason the technical difficulties will doubtless be overcome and the mercury rectifier will find general application for all purposes in changing from alternating to direct current.

THE THEORY OF THE MERCURY RECTIFIER

To get an approximate understanding of the mercury vapor rectifier, it will be necessary to consider the peculiar characteristics of vapor conduction of electricity. There is good evidence that so-called "ions," or small electrically charged particles exist almost universally in gases. The positive ions are apparently atoms or molecules of the gas having a certain unit positive charge. Just what the nature of this positive charge is may not be absolutely certain, but for our purposes this is not important. The negative ions, on the other hand, appear to be exceedingly small particles commonly called "electrons" or "corpuscles" having a similar unit negative charge and an apparent mass of about 1/1700 that of a hydrogen atom.

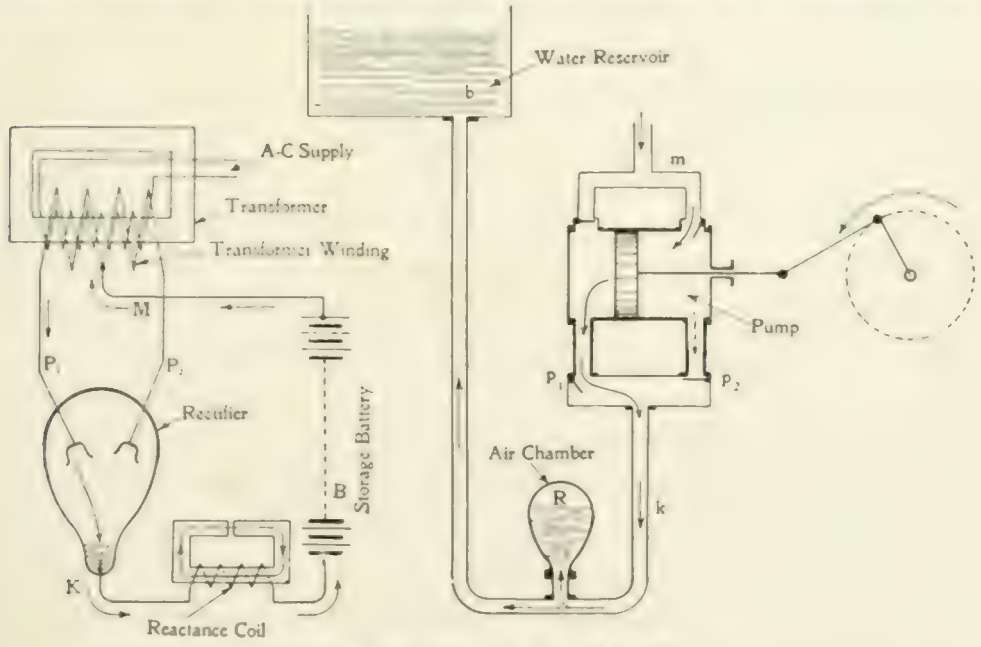


FIG. 2—HYDRAULIC ANALOGY

This mass appears to be due to the negative electric charge and the lines of force set up by it and not to have any material existence at all.

Now, ions, particularly negative ions, seem to be almost universally present in the atmosphere. Under high electric stress their number may increase indefinitely as a result of their rapid movement and collision with molecules of gas and with electrified terminals or electrodes. If a potential is applied between two parallel plates in the open air, there is a slight flow of current, even though the applied voltage may be very low. This current, however, is not proportional to the voltage but appears to increase somewhat as the potential difference increases, and reach a maximum where increase of potential,

without other change, brings no further increase of current. Apparently, the ions that float into the electric field are driven by it in such a way that there is an effective transfer of charges across from the negative plate to the atmosphere and from the atmosphere to the positive plate. An increase of electric force increases the velocity of these ions but there can be no further increase of conduction beyond using all the ions that naturally float into the electric field. This is a form of conduction in a gas in which there is no additional production of ions by the electric field. If the potential gradient between the electrodes increases, a point may be reached where the electric field begins to cause increased ionization of the gas due to the impact of the moving ions upon free molecules and upon the electrodes. This increases the conduction but may still give a stable condition. The corona between high voltage transmission conductors is an example. Where ionization of the gas is taking place, there is usually an accompanying glow of faint light. If conduction of this type is pushed still harder, the result is the formation of an arc which, in itself, is unstable and tends to increase, unless controlled by other parts of the circuit. The reason for this instability is that, whereas, with the two previous forms of conduction, an increase of current necessitated an increase of potential difference, an arc, in general, requires less potential drop with an increase of current.

Now, if the air or gas pressure is reduced, all of the above characteristics become, in a way, accentuated and take place at much lower voltages as the gas pressure becomes lower, until a certain critical pressure is reached where, at the approach of complete vacuum, the rarefied gas tends to become more nearly an insulator. As described by Prof. J. J. Thompson,* the action of a vacuum tube during the glow discharge (corresponding to the corona in the atmosphere) is somewhat as follows:—At the negative terminal or cathode, there may be a slight luminescence and then a band of dark space called the "Crooks dark space." There is a large drop of potential through this space called the "cathode fall of potential." At the border of this dark space is a luminous band known as the "cathode glow" and having very little potential drop. After this comes another dark band known as the "Faraday dark space" with a low potential drop gradually merging into the "positive column" a considerable stretch of glow sometimes striated and with moderate potential drop which reaches to the anode with perhaps a slight increase of potential drop near the anodes. The distribution of po-

*In "Electric Conductivity of Gases."

tential and the light and dark bands are shown graphically in Fig. 3.

The explanation given is that up to a certain voltage between terminals, there is no continued conductivity as the number of free ions is limited and the negative ions are soon all driven to the positive terminal and vice versa, and the formation of new ions is impossible, since the velocity of the moving ions is not great enough to supply the required energy. As the potential difference increases, a point is finally reached where the impact of the positive ions on the cathode, or on the molecules of gas very close to the cathodes, causes the release of electrons or negative ions which are repelled with great velocity through the dark space, and at a certain point begin to strike molecules of gas actively and form new positive and negative ions which migrate in their respective directions to the

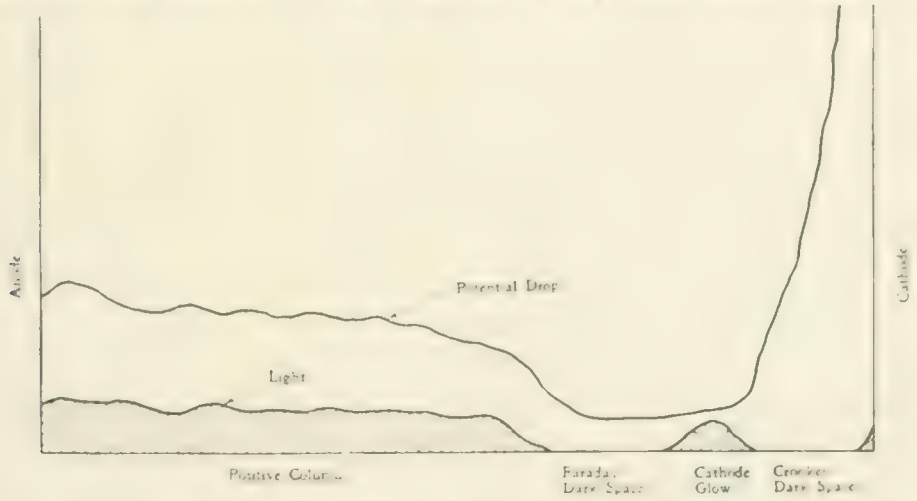


FIG. 3—GRAPHIC REPRESENTATION OF THE DISTRIBUTION OF POTENTIAL AND THE LIGHT AND DARK BANDS IN A VACUUM TUBE

cathode and anode. This is a continuous process so long as the potential difference is maintained. The glow or luminescent spaces appear to be the localities where ionization of the gas is taking place and where positive and negative ions are about equally distributed. The key to the conduction of the current is apparently the breaking off of electrons from the cathode and their expulsion violently from it as negative charges. This breaking off of electrons from the cathode is called "ionization at the cathode" and apparently takes place when a certain critical amount of energy per unit is released by the impact of positive ions on the cathode. If the pressure at which the above described characteristics begin to be visible is still further reduced, the Crooks dark space expands and the cathode drop increases. It would appear that the pressure being lower and the positive ions fewer it is necessary that more energy per ion be

imparted by the electric field to maintain cathode ionization and, therefore, conduction. Consequently, the cathode drop increases and covers a greater distance, and the positive ions, accelerated through a longer path, accumulate enough more energy to maintain the process of ionization.

While the cathode drop and the length of the Crooks dark space may not be directly connected, yet both seem to be a function of pressure. The dark space is probably controlled by the mean free path of the negative electrons in the gas, and the length, l, is roughly given by the expression $l = a + \frac{c}{p}$, where a and c are constants and p is the absolute pressure of the gas. Similarly the cathode drop v apparently follows the approximate law of $V = K + \frac{h}{p}$ when K and h are constants. For a considerable range of pressures, the cathode drop is in the region of 400 to 500 volts. As may be seen, however, if p becomes very small, the value of V may become very large and take an infinite value when $p = 0$. From this, it would appear that the only absolute insulating medium is a perfect vacuum.

Experiments indicate that when the pressure is much reduced the Crooks dark space expands to touch the walls of the containing tube and spreads far towards the anode. The current then falls rapidly and the cathode drop increases to a very large value. Now this is the condition existing at the momentarily inactive anode of a mercury rectifier when the alternating current is passing through zero value; at the instant the current is attempting to flow in the reverse direction the anode is, in effect, really a cathode of a vacuum tube of very high vacuum and large cathode drop. The Crooks dark space has, in general, expanded to fill the entire tube or bulb. There is usually a slight leakage current between the positives or anodes, especially when the bulb is warm and the mercury vapor pressure thereby increased, but with the bulb cold and the dark space expanded, as indicated above, the vapor really becomes almost a perfect insulator.

Now, when the normal load current is passing, it is interesting to note what is occurring between the active anode of the rectifier and the mercury pool. To all appearances there is here a true arc, as all of the characteristics of the mercury arc seem to be identical with those of the metallic arc. An arc, like combustion in the atmosphere, is self-maintaining; that is, having once been started by any cause, there appears a focus of negative ionization where there is sufficient energy released to maintain continued ionization unless the

current reaches too low a value, when the bombardment of the positive ions on the negative spot no longer produces a sufficient supply of negative ions or electrons and the arc ceases, and will not restart unless the required conditions for starting are established. With an alternating current, the arc would not be maintained unless the conditions were such as to maintain a conducting vapor between the electrodes.

The general characteristics of the mercury arc in the vacuum chamber of the mercury rectifier are in every way identical with those of any metallic arc in the open air, as will be evident from the three following statements:—

1—The circuit is unstable unless controlled by resistance or reactance in other portions of the circuit.

2—The drop is approximately constant but tends to lower in value with increase of current.

3—A supplementary electrode in an ordinary direct-current arc will pass current to the cathode if connected in any way to the positive side of the circuit, but will not pass any current if connected to the cathode or negative side of the current, since the negative side of the arc is localized in one spot. If, however, this supplementary or exploring electrode is connected to the negative through a separate source of e.m.f., current will flow from this supplementary electrode to the cathode but not from the cathode, since the negative end of the arc is not only localized in a spot but is essentially negative, and current can therefore pass from *any* positive source to the negative or cathode of the arc, but not the reverse. In other words, an ordinary arc possesses rectifying characteristics. The mercury vapor rectifier, moreover, appears to be nothing more mysterious than a vacuum tube in which the vapor pressure is very low and in which an arc plays successively from one of two or more anodes to a mercury cathode and in which the idle anode becomes a cathode of the vacuum tube with the usually high cathode vapor drop and Crooks dark space much accentuated, due to the low pressure of the mercury vapor and the absence of all contaminating gases.

Fundamentally, the rectifying characteristic is due to the marked difference between positive and negative ions in regard to mass and consequent velocity and energy storing capacity. Our knowledge of the constitution of matter and its relation to electric conduction is, in reality, limited and just why an arc should continue

when once a certain rate of ionization at the cathode surface has been started and when it would not start itself, is a mystery of the same class as that of fire which burns when once the fuel has been ignited. Future experimental information will doubtless throw further light on these physical and electrical relations.

There is apparently a critical rate of ionization at the cathode surface. During the glow discharge, the rate is below this critical value. A slight reduction in rate of ionization, and consequent current flow, necessitates a broader Crooks dark space and a greater cathode drop, and the other parts of the tube give up some of their drop to the cathode space to maintain ionization with the reduced current. The conduction is therefore stable, as the essential portion of the circuit where the cathode drop is located is balanced by drop of a resistance nature in the other portion of the tube nearer to the anode. There are barely enough ions produced to carry the current, and an increase of voltage increases the number of ions produced per second and therefore the current. At the critical rate, however, where the arc appears, more ions than needed are produced and the current will automatically rise to a short-circuit value unless limited by external portions of the circuit containing impedance.

The expression of the above principles combined with various other empirical data make up the following rules which control successful mercury rectifier design and operation so far as the rectifier proper is concerned:—

1—The pressure due to gases other than mercury vapor must be kept low because the molecules of such gases both act as inert barriers and retard the flow of ions and, if numerous enough, reduce the dimensions of the Crooks dark space and consequently the arcing voltage and rectifying power. Pressures due to such gases must usually range between 0.001 and 0.020 millimeter for satisfactory working of mercury rectifiers.

2—The pressure due to mercury vapor must also be kept low and between certain limits. This is particularly true if the rectifier is to deliver a direct-current voltage much above 150 volts. If the mercury vapor pressure is too low, due to the chamber being too cold, the arc will become unstable and will be hard to start and tend to go out. This is apparently due to the attenuated condition of the vapor and the consequent difficulty of maintaining ionization. If, on the other hand, the mercury vapor pressure in the vicinity of the anode rises too high, the Crooks dark space contracts and the cathode

drop at the inactive anode takes a low value, and high leakage begins. The effect of this high pressure is rapidly cumulative, as the high leakage increases the energy loss and this again increases the pressure until a short-circuit, or so-called arcing condition develops. The above requirement as to control of the mercury vapor pressure is most important if high potentials are rectified. Although the cathode drop remains in the region of 350 to 400 volts, even at quite high vapor pressures, and is therefore sufficient to rectify 100 volts direct-current, this would utterly fail to handle an arc light circuit of 3 000 volts or more.

3—The anodes should be shielded or located in pockets separated somewhat from the main bulb chamber. This requirement is however intimately connected with the question of temperature, since a secluded pocket tends to permit a local rise of pressure around the anode which defeats the purpose for which it is used. The reasons for shielding the anode are two. First, to protect the anode from being spattered with drops of mercury from the cathode pool. Such impinging drops vaporize suddenly and cause local pressure with tendency to short-circuit. Second, as already mentioned, the cathode drop and consequently the rectifying power increases enormously when the Crooks dark space enlarges until its borders reach the walls of the surrounding chamber or tube. For this reason a much higher and more stable rectifying power is obtainable for given pressures when the anode is in an enveloping pocket than when in the same large open chamber as the cathode pool. As before mentioned, however, the pressure must be kept down or the Crooks dark space shrinks again to very small dimensions around the surface of the anode and the advantage of the anode chamber or pocket is at once lost. For that reason either these anode chambers have to be kept cool by special means or a balance must be maintained between the shielding obtainable and the openness of the anode chamber to permit relief of local pressure into the main bulb chamber. The result is that an anode chamber which much secludes the anode must be very carefully controlled in temperature and then gives a high rectifying



FIG. 4.—RECTIFIER BULB FOR SUPPLYING CURRENT TO 50 ARC LAMPS AND CAPABLE OF DELIVERING 7 AMPERES AT 4000 VOLTS.

power. To permit this accurate temperature control necessitates that such an anode chamber be external to the main bulb and the bulb immersed in some fluid which is kept at an approximately constant temperature. If a much more open anode chamber is used, however, and kept within the main bulb space the extreme maximum of rectifying power may not be quite so great but a very much wider range of temperature control is permissible with good operating results. Such an interior chamber maintains the vapor about the anode at a fairly uniform temperature and keeps the pressure low, since any excess pressure easily flows out into the main chamber where the pressure can easily be kept low.

4—The anodes and anode stems must be freed from occluded gas and there must be no crevices that can harbor gas or mercury globules. Most metals contain occluded gases, such as hydrogen, etc., and graphite is saturated with gas and water vapor. Under the influence of temperature and electric stress such vapors may be given off irregularly in operation, thereby momentarily reducing the cathode drop at an inactive anode with a resulting short-circuit between anodes.

It may therefore be seen that in the design of mercury rectifiers there are certain factors that are antagonistic and the effort to gain by one device is easily thwarted by a corresponding disadvantage. To this is added the inherent technical difficulties of glasswork, which must be highly perfected, since the glass is subject to considerable mechanical and electrical stress. It is therefore necessary to balance one advantage against another so that by compromise the best results may be obtained.

LIGHTING OF A SMALL JEWELRY STORE

E. M. SMITH

THE requirements for the correct illumination of stores in which jewelry is to be exhibited are quite complex. Whether the exhibition be of precious stones, of cut glass, or of gold or silver, a large part of the pleasing effect of jewelry is produced by the reflection of light from polished surfaces or facets. In order to secure a high degree of reflection, the predominating policy of jewelry stores has been to use large numbers of small, high intensity units. From the illumination standpoint, these are seldom properly placed and shaded. Usually the result is a rather gaudy, glaring appearance giving a repelling rather than an inviting atmosphere. Thus while one prime requirement for the sale of jewelry by artificial light—that of having plenty of light—has been met, other features have not been given sufficient attention.

The general impression given by such stores should be cheerful and attractive and not glaring. This means that the general illumination should be diffused and sufficient to give a pleasing appearance but not of sufficient intensity to detract from the effect of the special lighting. It should also be furnished in a not too conspicuous manner. Show cases should be lighted brilliantly, but if possible from concealed light sources. As the best results when inspecting jewels are secured by light from so called "point light sources," special attention should be given to the proper illumination of the display surface, both as to the source of light and its color effect.

The jewelry store whose interior is shown in Fig. 1 affords an excellent example of a method by which very satisfactory results have been secured both as to general and specific illumination. The general lighting of the room is secured from four 500 watt clear tungsten lamps equipped with "Frink" direct-indirect reflectors suspended in a line down the center of the room as shown. The ceilings are of white metal and the illumination produced by the combination is soft and restful to the eye.

Since jewelry cannot be displayed to advantage under a diffused light, twelve chain drops, five feet apart, were placed directly over the show cases. These are equipped with 60 watt clear tungsten lamps and focusing type Holophane reflectors. Over these reflectors are metal caps, spun to conform with the shape of the reflectors and lined with light blue enamel. This was done to accentuate the

blue from the lamps, thereby closely approaching daylight color effects while still retaining the advantage of point sources of light to give good reflection. The metal caps also serve to minimize the effect of glare in the room. The fixtures were finished in statuary bronze in order that they might harmonize with the wall cases. If brass fixtures had been selected, the drop lights especially would have been much more conspicuous.

The side wall cases are specially lighted by five 35 watt tungsten



FIG. 3—INTERIOR VIEW OF STORE OF BERMAN JEWELRY COMPANY, CLEVELAND, OHIO.

linolite lamps in each section. These are completely hidden from view when the cases are properly closed, and serve to bring out all the beauties of the cut glass and other ware displayed therein.

The complete effect of this system of illumination is exceptionally pleasing and attractive. The light sources are hidden from direct view, while an average intensity of six foot-candles is obtained. Every detail of the objects displayed is sharply emphasized, while cut stones and glassware may be shown to excellent advantage.

STANDARDIZATION IN MANUFACTURING

AN INDUSTRIAL EXAMPLE (Concl.)

H. F. CHADWICK

EFFECT OF STANDARDIZATION ON STOCK AND PRODUCTION

KEEPING engineers and draftsmen posted in regard to standards is only one of the problems that confronts the standardizer. For instance, designers often have the mistaken impression that standards decrease the amount of initiative required on their part and thereby place a limitation upon the exercise of their originality. It has been found in actual experience that even with the very best efforts that can be put forth in establishing standards, a large amount of original work will still be required in developing new apparatus, even with all parts standardized.

In manufacturing concerns having a diversified product, the amount and the number of kinds of material necessary to be carried in stock is tremendous. It is of the utmost importance to reduce the number of ledger accounts to a minimum, and to use only stock sizes wherever possible. The specifying of a special material or a special size of material involves not only delay in completing apparatus, but also additional clerical work, storeroom space and investment. It is sometimes contended that by holding to standard screws, for example, we are making the tail wag the dog; that is, the apparatus is being designed to fit smaller parts used in its construction. In a measure this may be true, but with a reasonable list of standards the design can almost always be made equally good whether standard or special parts are used, and the advantages of following standards are so obvious that there should be no hesitancy on the part of designers in making slight changes in order to make possible the use of standard parts.

There are many small parts commonly used on machines and apparatus which have the same general application. This does not refer to bolts, screws and other articles generally classed as hardware, but rather to such parts as terminals, tie rods, handle grips, connectors, bearings and many other similar parts. In many shops it is not unusual to find from fifteen to fifty shapes and sizes of a certain part when four or five would answer the purpose just as well. As a consequence small quantities of the fifteen or fifty sizes are produced, each size requiring a special set-up of the machinery, and often the quantity is so small for each size that the job cannot be done on an automatic machine. By standardizing and reducing the number of designs to a minimum, it is then possible to make each design in large quantities for stock; on account of being made in quantity the processes of manufacture can be materially cheapened,

besides giving a uniformity of product at all times. Further, there is a considerable saving in such standards due to the fact that each piece standardized may be carried in stock by a designating number (called by the Electric Company a style number), and drawings can refer to this number without making a detail of the piece.

Variations in design not only affect the amount of stock to be carried, but also in many cases cause the making of special tools and appliances. As an example, nearly every well equipped firm has a complete set of tools for cutting and testing all United States Standard threads, and often many other threads which are considered standard by the firm. The Electric Company has a list of standard threads which correspond with the U. S. Standards for ¼ in and above and a list of standard fine threads, which can be used



FIG. 8—TOOLS REQUIRED IN CASE OF VARIATION FROM STANDARD THREAD

when the standard thread is too coarse. It is seldom realized how many tools are required to produce a thread, and it is commonly thought that the question of threads is of so little importance that it is not worth investigating. Fig. 8 shows why it is necessary to adopt a standard and live up to it. The Electric Company's standard thread for two-inch diameter is 4 1/2 threads per inch, and the standard fine thread is 12 threads per inch. If 13 threads per inch should be specified, it would be necessary to make the six tools shown in Fig. 8, viz., transfer gauge, tool room record plug gauge, working plug and ring gauge, tap and die, costing $25.00 to $50.00.

THE WORK OF THE STANDARDIZER

Standardization is a comparatively simple matter when the subject to be standarized is a new one. Of course it often happens that there has been no previous investigation of the subject,

and consequently no data for comparison. In such a case a very careful investigation is necessary in order to establish a standard which will meet all possible requirements. Even with the most careful preparation contingencies will arise where it is impossible to use the standard, but such cases should be very rare. When the subject to be standardized is an old one, the work of the standardizer is much more difficult. First it is necessary to find out what has already been done, and what the standards of other companies or individuals are, if there are any in existence. Consider, for example, the method of figuring the size of pulley which should be made standard for a certain motor. Nearly every engineer has some favorite formula, which he may in turn have obtained from some textbook or handbook, or which he has obtained from some other engineer who has used it with good results. Occasionally an engineer prefers to work out his own formulas. Such a man would obtain slightly different results from those who use textbooks or handbooks. One man will swear by Kent, another by Foster, Supplee or Merriman, and each is generally able to produce some proof that the formula which he has adopted is the best. Some figure a single belt to be approximately 3/16 in. thick, a double belt 3/8 in. thick, and a triple belt 9/16 in. thick; others measure samples of belts and obtain positive figures like 7/32 in. for single belts, 3/8 in. for double belts and 1/2 in. for triple belts, without taking into consideration the fact that there is a large variation in the thickness of hides, and that while the average thickness of single belt leather is not far from 3/16 in., some dealers furnish heavier and others thinner material. A common figure for the limit speed, for single belts, at which the horse-power transmitted becomes a maximum in 4800 feet per minute. Some, however, figure at a mile per minute and even as high as 5800 feet per minute. Other points of variation are the percent of slip allowed, the initial tension in pounds per square inch of section of belt, the limits at which double and triple belts should be used, and the maximum allowable fiber stress in the shaft. With such a variety of formulas and methods, it is evident that the standardizer must make a thorough study of every phase of the question, and suggest some method which can be substituted as standard.

When a part or element of a machine or piece of apparatus is to be standardized, there are many other considerations besides those just mentioned. In addition to the selection of a suitable standard for future work, it is often advisable to substitute the new standard for the old designs already used. In such cases it must

be ascertained with surety that the new part can be used without seriously affecting other parts used with it. The amount of stock of old designs on hand must also be carefully considered. The material is an important item, and it is often found that a cheaper material can be used with just as satisfactory results. Very often a part could be made in any one of a half-dozen ways and be entirely satisfactory, but the factory happens to be equipped to manufacture in a certain way, and if any other method is specified the shop must change its methods and tools at a considerable expense.

The good effect on the factory, from a manufacturing standpoint, in having as many duplicate parts as possible can hardly be estimated. It makes cheaper production; it allows the use of automatic machines in place of very expensive handwork; it reduces very greatly the amount of stock to be carried; it simplifies the bookkeeping and handling of stock; it allows quicker deliveries of finished apparatus because parts can be taken from stock; in fact, there is no standpoint from which the standardization of parts does not show a decided saving. Many do not appreciate that, while the addition of a single special part or special shape is in itself a comparatively insignificant thing, the total effect is detrimental in the extreme to the commercial production of apparatus. However, it is obvious that special parts must sometimes be designed to give the correct electrical or mechanical performance.

SUMMARY; BENEFITS AND DANGER ELEMENT

In our enthusiasm for standards we cannot fail to recognize the fact that there is one "danger" element. Standardization offers immediate returns which are most attractive. From a chaos of minute differences in methods we get a uniformity of manufacturing conditions and an interchangeability of parts which is unquestionably necessary for economic manufacture. In place of introducing unnecessary individuality into every design, standard patterns, tools and sizes are employed. The point to be carefully watched is that the standards are elastic. The evolution of engineering is so rapid that a standard which admits of no adaptation to new conditions, which is as fixed as the laws of the Medes and Persians, is a very grave menace to engineering progress. Standardization and the economies that come with it have come to stay; but on account of the almost yearly modifications in various lines of industry, due to the advances attained by engineering research, standards must be subject to frequent revisions and must possess much elasticity.

EXPERIENCE ON THE ROAD

AN IMPROVEMENT ON THE PRONY BRAKE

E. W. HENDERSON*

NO method of testing small motors directly by measuring electrical power intake and mechanical power output is as popular as that by prony brake, inasmuch as this method gives data from which results are easily and quickly calculated. The prony brake of the ordinary form consists of a band of some sort which is attached firmly to a single brake arm on one side of the motor pulley, passes round the pulley and is attached to one end of the arm through some adjusting screw by which the tension on the band can be regulated. The other end of the arm rests on a scale, the motor being driven in such a direction that the arm bears down on the scale and registers the weight applied, from which, knowing the motor speed and pulley diameter, the brake horse-power of the motor may be calculated. When the brake is of the above form it presents several bad features. One of these is the impossibility of maintaining a constant given load for any appreciable length of time. If the pulley heats up slightly, it expands, binds the band on the pulley and increases the load. Or the constant vibration of the arm may loosen the tension of the band and decrease the load. Such a brake, therefore, needs constant attention in order that the proper load may be maintained. This in itself is a disadvantage, but of far greater import is the fact that as the operator's hand is almost constantly on the adjusting device, the load as registered by the balance is not correct and, in case of small motors, the error may amount to quite a large percent. It is the purpose of this article to describe a brake somewhat after the fashion of the prony brake, but which eliminates the bad features of the latter without losing the simplicity of calculation.

The brake arm is double, as shown in Fig. 1. The upper part A is hinged to the lower part B at C. The point C should be as far as possible from the center line through pulley D and the

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hinge is therefore located as near the end as possible—allowing convenient room for the adjusting screw *E*. One end of the rope or band is attached to a rectangular link, this link being shaped to a knife edge on the inner edge of its top side, the knife edge resting on a grooved plate *F* imbedded in upper arm *A*. The other end of the band is attached to an adjusting screw *E* in the usual way. A hanger is suspended from *B* on a knife edge and weights can be placed on this hanger as on any ordinary scales. The upper arm *A* is supported from some standard through a spring balance *H* (preferably of the dial type). A very simple and convenient standard can be made from three-quarter or one inch pipe. The connecting link to the balance rests on a knife edge in *A*. The knife edges in *A* and *B* consist simply of ordin-

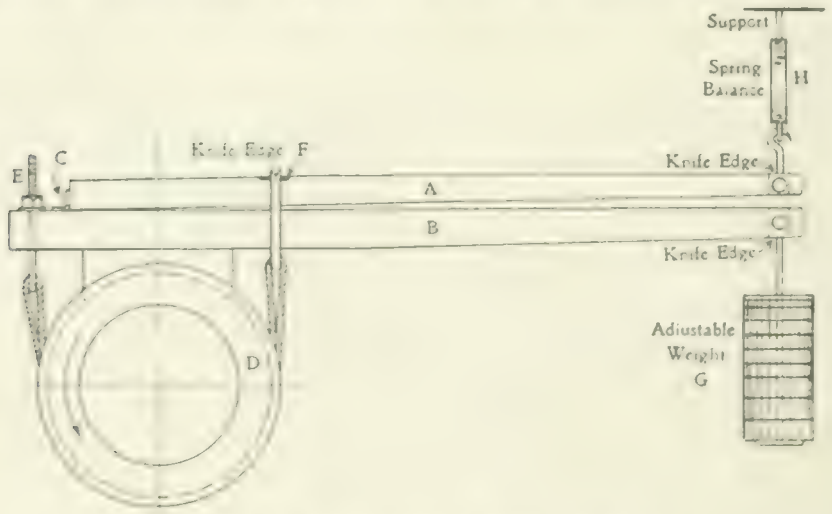


FIG. 1—SELF-ADJUSTING TESTING BRAKE

ary machine bolts passing through eyes in the hanger and balance attachment—these bolts being filed to an edge on their bearing surface.

The motor is driven in such a direction as to lift up on the weight *G* and the difference between the weight suspended at *G* and the weight registered on the spring balance is evidently the gross weight lifted by the motor. To this must be added the weight of the brake arm in calculating the brake horse-power. The effective weight of the arm is readily found by tying *A* and *B* together with a light cord or wire, and, with no weight at *G*, (other than the hanger) noting the weight registered on the spring balance for each direction of rotation of the motor, the speed being the same in both directions. Half the sum of these two weights will be the weight of the brake arm, since, with one direction of

rotation the weight registered will be the weight of the arm plus the friction on the pulley, and with the other direction of rotation the weight registered will be equal to the weight of the arm minus this friction.

As the load at G is increased and the attachment on the balance H comes down, the arms A and B may be kept horizontal by having an adjustment above the balance such that it can be raised or lowered, or the link connecting the balance to A may be made adjustable.

A very sensitive balance H can be used and may be protected from over strain in case the motor stops suddenly by placing a support just below the weight G, such that the weight will drop upon it.

The brake horse-power is calculated in the usual way. The great advantage of this arrangement is that the motor may be run for any desired length of time on any one load without attention, since if the band tends to tighten on the pulley the lower arm B is lifted towards A and the tension on the band is automatically released. The arms A and B should be suspended horizontally and while it is impossible that they should both be exactly horizontal, the distance between them at the ends farthest from the pulley need not exceed half an inch and the error therefore, is negligible.

The above brake was brought out by Prof. L. W. Gill, of the School of Mining, Kingston, Ontario, and has been found so superior to the old prony brake that the latter has been discarded altogether in our laboratories. The load can be adjusted readily and will be maintained constant as long as desired.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

742—Transformers Star vs. Delta-Connected—*a*—Is it possible to raise the power-factor by connecting three single-phase transformers in star instead of delta, on a three-phase circuit? Please advise regarding both loaded and unloaded transformers. *b*—Would you consider it in any way detrimental to the life of three single-phase transformers, 1 100 volts secondary, 6 600 volts primary, to connect them in star without grounding the secondary? The primary is grounded. F.H.W.

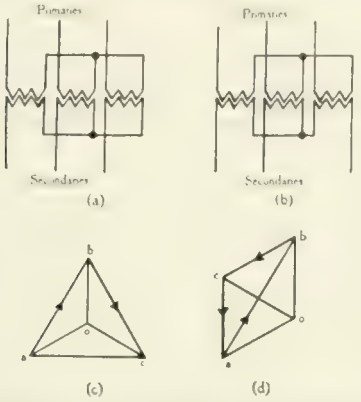
a—If the transformers are changed from delta to star connection on primary and secondary, the supply voltage should be increased 1.73 times; this will mean a smaller line current and, therefore, less reactance and a better power-factor. This is entirely due to the increase in line voltage, as transformers designed for this increased voltage could be connected in delta with the same improved power-factor. The power factor at no-load will be the same as with transformers connected in delta. If the transformers were connected in star on primary and secondary, and the supply voltage not increased to the star voltage of the transformers, the output of the bank would be decreased to 58 percent of the rated capacity; in this case the power-factor at no-load will be improved as the voltage across each transformer will be decreased, therefore causing a smaller exciting current.

b—Transformers designed for operating at 1 100 volts, three-phase delta should be able to operate in star at 1 900 volts without grounding the neutral, with no danger of shortening the life of the transformers. J.F.P.

743—Operation of Turbo-Generator Plant at Increased Power-Factor—In our plant there are two 500 kw steam turbines each direct-connected to a 650 k.v.a. generator. The load at times calls for 1 200 amperes for a few minutes and often hangs on at 1 000 amperes with 75 percent power-factor for a long time. At such times we are obliged to run both turbines, as the normal current is 783 per machine at 480 volts. Is there any way of operating this plant so that we can disconnect one generator and use it as a synchronous motor? Is this scheme practical, and if so, what results would ensue? Would the current drop to within the limits of allowable heating? F.M.

The currents given for the generators indicate that they are three-phase machines, with 783 amperes as normal full load; then, 1 000 amperes represent only 28 percent overload, and 1 200 amperes 53 percent overload on one machine. If the overload persists for only a few minutes one machine ought to be able to stand it, provided it is possible to hold up the voltage. It is important to know, however, whether the machine will do this without dangerous heating; if not, and the turbines are operated condensing, very considerable economy can be effected by operating one machine as a synchronous condenser, starting, if need be, first by steam, so as to reduce the losses. The power-factor of the loaded machine could of course be brought very closely to 100 percent without difficulty, which would allow for increase of load at a more economical point for steam economy of the first machine. But as it stands, if the figures given are correct, the loads stated respectively for "long time" and for "a few minutes" are so close to ordinary normal guarantees for such operations that there ought to be no serious difficulty. Thermometers, however, can tell the story. N.S.

744—Effect of Connection on Transformer Phase Relations—Three one k.v.a. transformers, ratio 50 to 2 000 volts, are connected in Y, both primary and secondary, as in Fig. 744 (a) and operation is all right. If the connection between one secondary and neutral is reversed, as in Fig. 744 (b); how will it affect the secondary voltage across phases? V.H.T.



Figs. 744 (a), (b), (c) and (d)

Denote the neutral point by the letter *O* and the terminals, numbered consecutively from left to right, by the letters *a*, *b* and *c*. Then the vector diagrams of low-tension voltages for the two connections are given in Figs. 744 (*c*) and (*d*). The effective values of the voltages across the phases are:—

In(c). $V_{ab}=V_{bc}=V_{ca}=1.73\ V_{oa}$

In(d). $V_{ab}=1.73V_{ob}$ and $V_{bc}=V_{ca}=V_{ob}$

745—Calculation of Resistance for Starting Boxes—Will you please give me a rule for calculating the resistance in re-winding starting boxes for direct-current motors. We often get them in the shop with no other data than that given on the name plate, the burned out wire being removed. For instance the following on name plate:—"4 Hp, 125 Volts, 23 Amps."—with 8 contact points for decreasing resistance. We have the "Climax" resistance wire tables at hand. D.B.S.

The total amount of resistance in a starting rheostat is found by dividing the line voltage by the starting current which is usually assumed to be the same as the full-load current of the motor. The resistances per respective steps are more or less empirical values but, as the resistance cut out each time should be approximately the same percentage of the total resistance remaining in circuit, it is evident that the first step will be largest and each succeeding step smaller. For an eight step rheostat the first step should be 20 to 25 percent of the total resistance and each succeeding step smaller, until the last, which should be four or five percent of the total resistance. The size of wire for each step depends on the heating. If a motor is to start in 16 seconds, with eight steps the contact arm of the starting box would stop two seconds on each button; that is, the first step would be in circuit two seconds and then cut out, the second step would be in circuit four seconds, etc., until the last, which would be in circuit 16 seconds. The total heating on any step depends on the resistance, current and time for which that step is in circuit, while the temperature rise of the resistance material depends on the specific heat, and the type of construction with reference to absorption and radiation of the heat, etc., so that it is impossible to give any one rule to cover all cases. See Nos. 300, Sept., 1900, and 630, Oct., 1911. H.C.N.

746—Compounding of Rotary Converter by Line Reactance—A 3 300 volt, three-phase, 60 cycle generator transmits power over a line having ten percent drop, through stepdown transformers to a rotary converter giving 600 volts direct current. What is the ratio of transformation in the transformers? If the resistance and reactance of line plus transformers, are 2 ohms and 5 ohms respectively, what range of voltage may be obtained on the rotary converter? F.B.B.

In order to give definite reply to this question it would be necessary to know the ratio of series field ampere-turns to armature, ampere-turns and other characteristics of the particular machine. Reference to the article by Mr. Jens Bache-Wiig on "Voltage

Regulation of Compound Wound Converters" in the JOURNAL for November, 1910, p. 860, will serve to cover your question. The method considered in this article is an approximate one, practically free of mathematics, for determining the results obtainable under given conditions with rotary converters of various design and with various conditions of line reactance.

747—Rotary Converter Booster Combination—We wish to maintain a pressure of about 600 volts at a distance of five miles from sub-station. This station now has two 600 volt, 25 cycle, 150 kw rotary converters in service. It is proposed to install one new 300 kw rotary converter, (without starting motor), remove starting motor from one of the 150 kw converters, direct-connect their shafts and make electrical connections as indicated in Fig. 747 (a). It is calculated that two

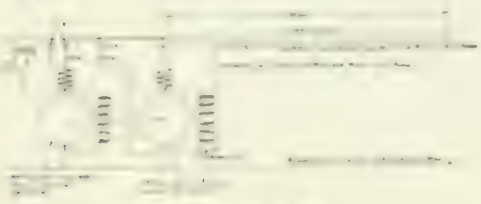


Fig. 747 (a)

miles of No. 5 copper will shunt sufficient feeder drop for field excitation on the booster to raise the voltage at the station 80 volts for every 100 amperes flowing. *a*—Will it be possible for the pressure to exceed 600 volts at any point on the trolley wire? *b*—Is the resistance of .33 ohms correct for the field circuit of a six-pole 600 volt, 150 kw rotary converter, with shunt field coils connected in multiple? *c*—With the arrangement shown will the booster about compensate for the drop in five miles of twin No. 4/0 copper feeders, and track? *d*—There was some question as to whether this machine could be made to commutate when handling heavy currents with low field excitation, and high armature speed. E.J.I.

a—With a booster system, so arranged, having once adjusted the system to give 600 volts at the ends of the line, more than 600 volts will not be obtained at any intermediate point. *b*—The resistance of the field will depend entirely upon the design of this particular machine. The size of wire, length of turn, and number of turns per pole would have to be given to determine this resistance. *c*—The ampere-turn strength of the series field, as well as the complete design of the booster, would have to be known to determine what voltage the series field is capable of generating at various loads. In view of the fact, however, that series fields are usually weak, it probably would not be possible to compensate for the drop in this way. *d*—The series field excitation is proportional to the current flowing, but as this excitation is small compared with that at which the machine is probably designed to operate, we anticipate very poor commutation with the converter run as a booster. R.H.N.

748—Operation of Induction Motor With Repulsion Starting Characteristics—In a motor of the single-phase, repulsion starting, induction running type, would there be any harmful effect if the motor were to fail to release the brushes or short-circuit the commutator, due for example to an overload, but continue to run as a repulsion motor? C.W.

These motors, as manufactured by various companies, will overheat in a short time, say 15 or 20 minutes, if loaded to the point where the governor fails to change them over from operation as repulsion type to operation as induction type machines. The commutator and brushes are not designed to handle a continuous current of a magnitude corresponding to the normal capacity of the motor, and it is therefore unsafe to allow the motor to stay connected to the line in case it does not reach a sufficiently high speed to short-circuit the commutator and thus convert the machine into an induction motor.

A.M.D.

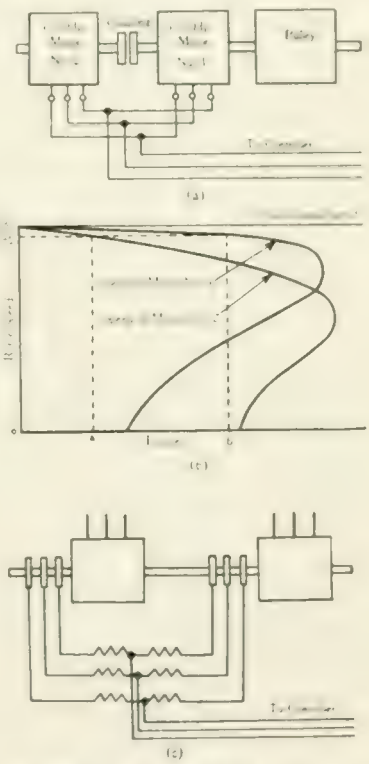
749—Starting and Protection of Small Direct-Current Motors—*a*—What is the largest type of direct-current motor, in horsepower rating, that can be safely started without a starting resistance to cut down the current while the armature counter-e.m.f. is building up? *b*—What special requirements should be asked for when switch and rheostat are located out of sight of the motor they are controlling, to comply with Rule *8*, Sec. *c*, of the National Electric Code?

K.W.A.

a—This depends on the design of the motor; practically any motor up to and including one-half horsepower capacity will start safely when connected directly on the line. By special design, motors up to 20 hp are made which may be safely started in this way. This does not take into consideration the question of the effect of such starting on the circuit to which the motor is connected, as regards voltage fluctuations. This, however, is not an important item unless the system or line is of limited capacity or so loaded that this feature has to be considered. *b*—When the switch and rheostat are located out of sight of the motors which they control, the approval of the local Underwriters' inspection department must be obtained in writing. The object of having the motor within view of the operator when he is at the controlling apparatus is to enable him to see whether the motor is starting properly. The Underwriters sometimes wave this requirement in special cases where they consider that it does not apparently affect the fire hazard. J.M.H. and D. H.

750—Control of Wound Secondary Induction Motors in Parallel—In an installation of several 175 hp, three-phase 25 cycle 600 volt wound secondary induction motors it is desired to increase the load about 95 percent, on the machines which these motors drive through rope transmission. Will it be practical and economical to couple two of these motors together on the same shaft and have them drive one machine, as per Fig. 750 (a)? The present controllers are hand operated and are ample to take care of 300 hp; there is also heavy grid type resistance in the secondary circuit. Please give a diagram of the best method of connecting the extra set of resistance in the secondary circuit. If there is any other way they can be connected to run together satisfactorily will you please explain in full. W.S.D.

Two induction motors may be connected to the same load, irrespective of their size and characteristics, provided each motor has its own controller, and the resistances are so adjusted that the load of the two motors is divided in the desired ratio. This can easily be done as long as the slip of each motor is not too small; at very small slip a slight change in the secondary resistance of one of the motors will cause a considerable change in the load. This is demonstrated in Fig. 750 (b). Assuming that motor *II* has a speed-torque curve of relatively greater drop in speed than motor *I*, and that the total required torque is equal to a+b; then motor *I* will

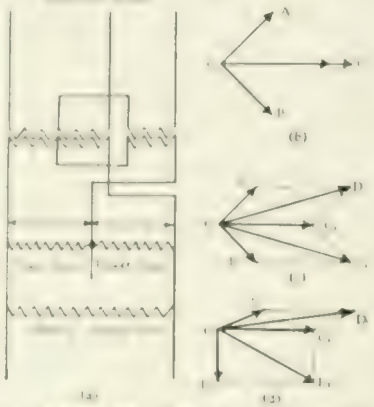


No. 750 (a), (b), and (c)

develop 5 lbs. torque and motor *II* only 2 lbs. torque, the torque of motor *I* being much greater than that of motor *II*. If the two secondaries of the motors were connected to a common controller circuit, as in Fig. 750 (a), it would then be necessary that both motors have exactly the same characteristics and that the two motors be so lined up relative to each other that they will operate exactly in phase in both primary and secondary. If this is not done there will be circulating currents through the two rotor windings, which will cause heating and prevent the motors from developing the required torque. Since it is very difficult to fulfill the above requirement it can hardly be recommended to connect the secondaries to one common controller circuit, unless a considerable resistance is also inserted in the connecting leads, as shown in Fig. 750 (c). Nevertheless, as a rule, the simplest and best method is to equip each motor with a separate controller circuit. H.C.S.

751—Unbalancing in Three-Phase—Two-Phase Transformer Arrangement—When three-phase current is changed to two-phase at 3000 volts, which supplies transformers for two-phase power and single-phase lighting, as in Fig. 751 (a), why are the two phases not balanced? One outside line carries about 12 percent more current than the other. J.S.W.

The condition observed is due to a difference in power-factor between the two-phase load and the single-phase load. Let vectors OA and OB, Fig. 751 (b), represent the two-phase e.m.fs.; then OC will represent the single-phase e.m.f. If the polyphase load has a power-factor of unity, then the current relations are as shown in Fig. 751 (c), where OA_1 is current due to two-phase load of phase OA; OB_1 that due to two-phase load of phase OB, and OC_1 that due to single-phase load. The resultants of OC_1 combined with OA_1 and OB_1 respectively, viz: OD_1 and OE_1, will be the currents in the leads. If, now, the power-factor of the polyphase load be, say 80 percent, the conditions will be as shown in Fig. 751 (d), the



No. 751 (a), (b), (c), and (d)

currents corresponding to those in (c). Thus OD_1 and OE_1 may have an entirely different effective value, dependent upon the difference in power-factor of the polyphase and single-phase circuits. C.F.

752—Change of Connection for Reversal of Shunt Motor With Commutating Poles—In changing the connections of a four-pole, shunt wound, direct-current motor having commutating poles, is there any advantage in changing the armature connections as compared with the method of reversing the field connections? If so, please explain. S.K.

For the control of a shunt motor with commutating poles, the method of reversing the armature and commutating pole connections offers a quicker means than that of reversing the shunt field connections, as the self induction of the shunt field winding and lag in the magnetic circuit cause a tardiness of reversal which is not involved when the armature and commutating pole are reversed. The relation of armature and commutating pole winding should of course always be kept the same, regardless of the direction of rotation of the armature, preferably by a permanent connection between them. J.M.H.

SEATTLE CONVENTION OF THE NATIONAL ELECTRIC LIGHT ASSOCIATION

The annual convention of the National Electric Light Association will be held in Seattle, June 10 14.

The principle items in the program are as follows:

Monday Evening—Reception and opening of exhibition.

Tuesday A.M.—Address of President Gilchrist; Reports of Committees on "Organization of the Industry"; of "Insurance of Expert"; "Progress"; "Library"; "Handbook"; "Question Box." Paper, "Expanded Loyalty," by Paul Lüpke.

Tuesday P.M.—First Commercial Session: 1. Address of Chairman of Section, H. J. Gille. 2. Address, *Commercial Development of the Electrical Industry,* W. W. Freeman. 3. Report of Committee on Membership, George Williams. 4. Report of Committee on Steam Heating, S. M. Bushnell. 5. Report of Committee on Electric Refrigeration and Ventilation, John Meyer.

First Accounting Session—1. Report of Committee on Uniform Accounting, E. J. Bowers. 2. Paper, *Incandescent Lamp Accounting of the New York Edison Co.,* W. H. Bogart. 3. Paper, *Handling and Accounting for Scrap Materials,* Chas. E. Bowden. 4. Paper, *General Filing Systems,* R. H. Williams.

First Technical Session—1. Report of the Meter Committee, O. J. Bushnell. 2. Paper, *Meter Setting,* S. D. Sprong. 3. Report of Committee on Grounding Secondaries, W. H. Blood, Jr. 4. Report of Lamp Committee, F. W. Smith. 4. Report of Committee on Electrical Measurements and Values, Dr. A. E. Kennelly (to be read with Lamp Report). 5. Paper, *Line Voltage,* R. E. Campbell.

Tuesday Evening — First Power Transmission Session—1. Address of Chairman, Henry L. Doherty. 2. Report, *The Use of Electricity for Irrigation and Agricultural Purposes,* C. H. Williams (illustrated by lantern slides and motion pictures).

Second Commercial Session—1. Report of Committee on Residence Business, J. F. Becker. 2. Report of Committee on Industrial and Commercial Lighting, E. H. Beil. 3. Report of Committee on Competitive Illuminants, F. H. Golding. 4. Report of Committee on Electric Adevrtising and Decoratove Street Lighting, W. H. Hodge.

Wednesday A.M. — Second General Session and Executive Session—1. Report of Rate Research Committee, E. W. Lloyd. 2. Paper, *The Desirability of a Central Station Load of Pumping for Municipally Owned Water Works,* Chas. A. Munroe. 3. Paper, *Educating Central Station Employees,* H. E. Grant (to be discussed in Company Section meeting, Thursday P.M.).

Executive Session (12 or 12:30)—1. Action on Report of Public Policy Committee, Arthur Williams. 2. Presentation of Proposed Constitutional Amendments, Frank W. Frueauff. 3. Report of Treasurer, G. H. Harries. 4. Election of Nominating Committee.

Second Technical Session—1. Report of the Committee on Terminology, W. H. Gardiner, Jr. 2. Paper, *New Current-Consuming Devices,* F. N. Jewett. 3. Paper, *Twenty-four-Hour Service in Small Central Stations,* Taliaferro Milton. 4. Report of Committee on Overhead Line Construction, Farley Osgood.

Second Accounting Session—1. Paper, *Proper Accounting for the Sale of Electric Devices,* L. M. Wallace. 2. Paper, *Scientific Management of an Accounting Department,* Franklyn Hevdecke. 3. Paper, *Central Station Motor Vehicle Costs and Their Distribution to Accounts Benefited,* E. C. Scobell.

Wednesday P.M. — Second Power Transmission Session—1. Paper, *Work and Publications of the U. S. Government Relating to Hydro-Electric Development,* J. S. Hoyt. 2. Report of Power Transmission Committee of the Association, J. R. McKee. 3. Report of Committee on Power Transmission Progress, T. C. Martin. 4. Paper, *Switchboard Practice for High-Tension Power Transmission,* Stephen Q. Hayes.

Third Commercial Session—1. Report on Electric Vehicles, L. R. Wallis. 2. Report: Electricity in Rural Districts, J. G. Learned. 3. Paper, *A Plan for Increasing Power Load,* H. W. Cope. 4. Report: *Selling Current to Larger Power Users,* Joseph Lukes.

Third Accounting Session—1. Paper, *Regulated Electric Light Accounting,* H. M. Edwards. 2. Paper, *Progress Made in the Uses of the Tabulating Machine,* Wm. Schmidt, Jr.

Wednesday Evening—Public Policy Session—1. Musical Program. 2. Reading of Report of Public Policy Committee, Arthur Williams. 3. Report of the Medical Commission on Resuscitation from Shock, W. C. L. Eglin. 4. Lecture, *Electrification of the Panama Canal* (illustrated by lantern slides).

Thursday A.M.—Fourth Commercial Session—1. Report of Committee on Cost of Commercial Department Work, E. L. Callahan. 2. Report of Commit-

tee on Contract Order Routine. F. L. Jones. 3. Report of Committee on the Commercial Index. E. L. Callahan. 4. Paper. *Operators and Their Instruction by the Central Station.* M. O. Troy.

Third Technical Session — 1. Report of Committee on Prime Movers. F. E. Moultrop. 2. Report of Committee on Electrical Apparatus. L. L. Elden. 3. Report of Committee on Underground Construction. W. B. Ackart. 4. Paper. *Care and Operation of Transformers.* W. M. McCordy.

Thursday P.M. — Third Power Transmission Session — 1. Report of Committee on Receiving Apparatus to Use on Transmission Lines. F. B. H. Paine. 2. Paper. *Corona on High-Tension Lines.* C. P. Steinmetz. 3. Report of Committee on Protection from Lightning and Other Static Disturbances. S. D. Spring. 4. Topical Discussions (time permitting).

Third General Session and Executive Session — 1. Paper. *Some Uses of Metals.* Dr. W. R. Whitney. 2. Report of the Committee on Street Lighting. John W. Lieb. 3. Report of the Committee on Memorials. T. C. Martin. 4. Report of the Committee on Constitutional Amendments. Frank W. Frueauff. 5. Vote on Constitutional Amendments. 6. Report of Nominating Committee. 7. Election of Officers. 8. Adjournment.

Company Sections Session — 1. Report of Committee on Award of Doherty Gold Medal. W. W. Freeman. 2. Discussion of Grant Paper. 3. The Proposed Company Section Lecture Bureau. T. C. Martin. 4. Experience Meeting as to Company Section Work.

The membership of the Association is now considerably over 11 000. The papers have been printed and distributed sufficiently in advance so that there will be plenty of time for study in the preparation of discussions, etc.

ILLUMINATING ENGINEERING SOCIETY

The Pittsburgh section of the Illuminating Engineering Society held the last meeting for the present season on May 17th. A symposium was presented on "Direct, Semi-Direct and Indirect Illumination" by Messrs. J. G. Henninger and T. W. Rolph, of the Holophane Company and S. T. Hibben, of the Macbeth-Evans Glass Company. The discussion was participated in by Mr. J. R. Cravath, consulting engineer; Mr. A. J. Sweet of the Holophane Company, and Mr. Preston S. Millar, general secretary of the society.

TRIP OF OFFICERS OF AMERICAN ELECTRIC RAILWAY ASSOCIATION

With the object of establishing a better understanding between public service corporations and the communities which they serve, the officers of the American Electric Railway Association have been making an 11 000 mile tour, beginning April 17th, and ending May 30th. Their trip includes such cities as Richmond, Va.; Atlanta, Ga.; Nashville, Tenn.; Birmingham, Ala.; New Orleans, Galveston, Dallas, Los Angeles, San Francisco, Portland, Vancouver, Seattle, Spokane, Minneapolis, St. Paul, Omaha, St. Louis, Louisville, Ky., Indianapolis, Cincinnati, Pittsburgh and Cleveland, Ohio. It is also one of the objects of this trip to increase the membership of the association and to cultivate closer relations with the remote members. Mr. Thomas N. McCarter, president of the Public Service Corporation of New Jersey, is president of the association.

A. I. E. E. MEETING

The May meeting of the Pittsburgh section of the American Institute of Electrical Engineers was held on May 14th. The principal paper of the evening was by Mr. J. H. Wilson, electrical superintendent of the American Rolling Mills Company, on the "Electrical Equipment of a Rolling Mill." The paper was discussed by Messrs. W. Sykes, Brent Wiley and W. Trinks.

The semi-annual convention of the Ohio Society of Mechanical, Electrical & Steam Engineers was held in Pittsburgh, May 16, 17 and 18. Papers were read by Mr. E. A. Uehling, of the Uehling Instrument Company; Mr. Ralph Beman, of the National Electric Lamp Association; and Mr. Francis Gangl, of the Northern Ohio Traction & Light Company. Numerous side trips were made to various manufacturing plants. Mr. E. M. Adams, of Akron, Ohio, is president of the society and Mr. F. E. Sanborn, of the Ohio State University, secretary-treasurer.

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The average edition of the Journal for 1911 was 12 375 copies. We have no free list whatever. All copies sent regularly go to our paid-up subscribers.

The Journal is published monthly, which ordinarily is often enough to call upon prospects in the engineering trades. It does not aim to be an electrical newspaper—its articles are of permanent value to be kept for future reference. We have already bound for our readers over 9 300 volumes.

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Inquiry from any prospective advertiser will bring full information regarding rates, etc. We give complete circulation distribution statement. Our stencil mailing lists are always open to interested advertisers.

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PERSONALS

Mr. Allen E. Ransom, manager of the industrial and power division of the Seattle district office of the Westinghouse Electric & Mfg. Company, has resigned as of June 1st to become assistant general manager of the Olympic Power Company, located at Port Angeles, Washington. This company has been installing a new power station to supply power from their 66 mile transmission lines to the towns of Port Angeles, Port Crescent, Sequir, Dungeness, Port Gamble, Port Wilson, Port Ludlow, Marette, Port Townsend, Fort Wurtler, Fort Flagler, the Bremerton Navy Yard, Port Orchard and other towns on the Olympic Peninsula.

Mr. L. H. Swinbank, assistant purchasing agent of the British Westinghouse Electric & Mfg. Company, Ltd., Manchester, England, has resigned his position, after a service of nine years, to take up a similar post with Messrs. Brunner Mond & Co., Ltd., Northwich, Cheshire.

Mr. Chas. F. Gray has resigned his position as district engineer in the Winnipeg office of the Canadian Westinghouse Company to accept a position with the Bruce Peebles Company, Winnipeg branch.

Mr. Joseph McKinley, contract manager of the Allegheny County Light Company, Pittsburgh, Pa., has been elected president of the County Light Section of the National Electric Light Association.

Mr. Edwin D. Dreyfus, for several years commercial engineer of the Westinghouse Machine Company, has recently taken up special work with the West Penn Traction & Water Power Company, Pittsburgh, Pa., and their allied interests. Before leaving his former position Mr. Dreyfus was presented with a handsome silver coffee set by his associates.

Mr. R. M. Hopkins has been appointed sales manager for the Pittsburgh district of the Allberger Pump & Condenser Company, with offices in the Farmers Bank Building.

Mr. C. F. Hewitt, who has been general superintendent of the East St. Louis & Suburban Railway Company for the past four years, has been elected vice president and general manager of the Des Moines City Railway Company.

Mr. Warren B. Flanders, of the steam turbine engineering department of the Westinghouse Machine Company, has resigned and accepted a position with the Havana Electric Company, Havana, Cuba.

Mr. R. F. Howard, formerly district engineer, connected with the Montreal office of the Canadian Westinghouse Company, has accepted the position as salesman in the Winnipeg office of the same company.

Mr. L. R. Parker, formerly with Westinghouse Church Kerr Company, and also district engineer in the Cincinnati office of the Westinghouse Electric & Mfg. Company, has accepted a position as salesman with the Canadian Westinghouse Company, Montreal office, and is located at Halifax, N. S.

NEW BOOKS

"Valuation of Public Utilities Properties"—Henry Floy. 385 pages. Published by the McGraw-Hill Book Company, New York City. Price, $5.00.

Quite comprehensive announcements have already been published describing this new work and its full contents have been thus made well known. One might gather a definite impression of the book from the listing of its well chosen chapters. Mr. Floy has succeeded most admirably in his presentations of the subject which, although not finally removed from the embryonic stage, is at the same time of extremely vital interest to the most of the engineering profession,

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and in which the engineer shall continually be more concerned. From direct experience, various authentic sources and court proceedings, the author has codified precedents, setting down deductions and principles, both convenient and valuable to the utility corporations and engineers. The book abounds with citations of leading legal cases, and further includes several representative appraisals. It is evident to the readers that the book has been prepared with painstaking effort and care in its various ramifications. E.D.D.

"The Art of Illumination"—Dr. Louis Bell. 353 pages, 171 illustrations. Published by the McGraw-Hill Book Company, New York City. Price, $2.50.

This is the second edition of this well known work. Great changes in illumination have taken place since the appearance of the first edition, both in the art itself and in light units available. After several general chapters on the principles of illumination, discussions are given of the gas incandescent lamp, the electric arc lamp, and the electric incandescent lamp. Several chapters are devoted to methods of figuring lighting of interiors, both large and small, and exteriors; with a closing chapter on illumination of the future. Those who have read other books by the author will know the general style to expect. Some of the illustrations seem somewhat out of date, due possibly to the older edition. This is a book for the general technical reader rather than the expert modern illuminating engineer.

"House Wiring"—Thomas W. Pope. 103 pages, 74 illustrations. Published by The Norman W. Henley Publishing Company, New York. Price, 50 cents.

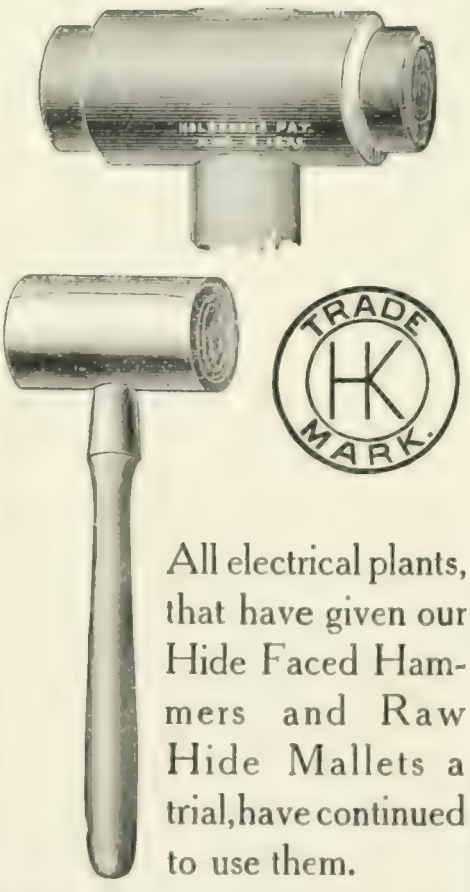
This little book is intended for the electrician and wireman and contains many helpful suggestions as to the best methods of solving wiring problems in accordance with the rulings of the National Board of Fire Underwriters.

"Knots, Splices and Rope Work"—A Hyatt Verrill. 102 pages, 148 illustrations. Published by The Norman W. Henley Publishing Company, New York City. Price, 60 cents.

This is a practical treatise illustrating and explaining methods for making the more common knots, ties and hitches, with chapters on splicing, nooses, mooring knots, etc.

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NEW BOOKS

"Power," by Charles E. Lucke, Ph.D. Eight sections, 316 pages, 223 illustrations. Published by the Columbia University Press, New York City. Price, $2.00.

Our daily life is regularly confronted with power problems of some form or another, and few perceive what magnitude and proportions the question and subject has reached. Every one should know something of the derivation of power and the various types of apparatus which are employed to control and place it at the service of mankind. Surely the engineer should acquire a broad point of view of this very vital phase in our industrial activities. The author has set about to portray readily lucidly in a popular style, the significance and import of power generation and utilization, and takes pains to avoid technical definitions which may confuse the mind. However, the book abounds with statements of many interesting engineering facts, which forcibly display the wonderful part this branch of science has taken in the affairs of man, particularly in modern times. In enumerating the headings of the various chapters which this book contains, their titles speak for themselves. I—The relations of mechanical power and machinery to social conditions. II—Means employed for the substitution of power for the labor of man. III—Essential elements of steam power systems. IV—Principles of efficiency in steam power systems. V—Processes and mechanisms of gas power systems. VI—Adaptation of fuels for the use of external combustion engines. VII—Water Power Systems and Hydraulic Processes. VIII—Social and Economic Consequences of the Substitution of Power for Hand Labor. The book comprises mainly the substance of a series of popular lectures delivered by the author. It enables a ready grasp of the underlying features and the correlation of different designs and elements which constitute the various characters of power plants, and will prove of educational value to both engineers and non-technical students.

E. D.D.

"Brazing and Soldering," James F. Hobart. 51 pages, 18 illustrations. Published by The Norman W. Henley Publishing Company, New York City. Price, 25 cents.

This is a small paper-bound pamphlet containing practical instructions for different methods of brazing and soldering.

THE
ELECTRIC JOURNAL

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Making Manufacturing Safe

The adequate safeguarding of factory tools and equipment is a subject which is of the first importance to the management of every modern manufacturing concern, for it involves the protection of life and limb of those directly engaged in the work of production. In every manufacturing establishment more or less attention has, of course, been given to the study of safety appliances, but too often it has lacked methodical investigation, with the result that many of the problems have been solved by bitter experience instead of by forethought.

As stated in the article by Mr. Pultney, on "Safeguarding Factory Tools and Equipment," in this issue, the safeguarding of machine tools is largely a matter for the tool builders, and in the future more will be demanded from them by the public-at-large than has been expected in the past. Safeguarding of machine tools is, however, but one phase of the problem and does not include other equally important features connected with manufacturing in general, such as the guarding of line shafting, belting, crane run-ways, electric wiring, industrial railway tracks and crossings, and protection from processes either hazardous in themselves or giving off noxious gases.

In attacking this problem systematically in any establishment, the work should be first placed directly under the charge of a thorough and mature mechanical engineer and preferably a man having had a wide and varied experience. To attain results most quickly, all appliances, processes and equipment should be segregated by him into three groups: first, those dangerous in the extreme and liable to cause serious accident at any time; second, those liable to cause accident but of a minor character, and, third, those in which the danger of accident is very remote and then but trifling in degree. Having accomplished this classification, the work of safeguarding should be proceeded with as fast as the situation warrants; cases which fall in the first classification being given first

attention, followed in due course by those of secondary importance, while cases of the third class may possibly be deemed not to require safeguarding at all. The assignment of a regular monthly allowance to cover such installations instead of the appropriation of a lump sum, will prove a most effective way of accomplishing the desired results. It should not be considered that the completion of the work as indicated will mark the close of the subject, especially if the establishment be one of any size; for as fast as safety appliances are installed they must be included in a system of regular patrol or inspection to insure their continued use and proper upkeep. Regular inspection is important, moreover, because from time to time new products are manufactured or slight changes in operating conditions take place, which sometimes nullify, in whole or in part, safety appliances which were effective when originally designed; such cases are thus brought under observation for change without delay.

Notwithstanding the very best endeavors to conserve life and limb, accidents apparently cannot be wholly guarded against by safety appliances. Gloves, loose blouses, wiping waste and other articles in common use are at certain times and under certain conditions the cause of totally unlooked for accidents. Such accidents are classed as "Hazards of the Industry," and result from unforeseen contingencies of one kind or another, no small proportion being due to the variable human element employed. It is earnestly to be hoped, however, that with increased knowledge of the various arts and processes on the part of manufacturers, and the proper instruction of employees regarding the fundamentals of such knowledge, these seemingly uncontrollable hazards may continually tend to reduce themselves.

ALEXANDER TAYLOR

The Organization Man

It is only in exceptional cases, now-a-days, that a man can have his own successful business; however, we must not say that it is only in exceptional cases that a man is in business for himself, even though the trend of modern business is unquestionably toward centralization and in most cases men must become parts of large organizations. In the large industrial companies, it is peculiarly true that a man does not need to grieve over the fact that he has not his own business. If he is truly an organization man he will consider himself a part of his company; successes will

be viewed with pride and complacency and failures will be a source of sorrow and chagrin. In this sense, he is not a hired man, for he is really working for himself.

It is true that modern business calls for the much maligned "red tape"; but who makes the rules and weaves the red tape if not the individual unit in the organization? Rules are made for a cause and if, through lapse of time or varying trend of business, a rule becomes a hindrance, the trouble should be remedied. A clear concise plan should be advanced to do away with the rule or to modify it so as to adopt it to actual conditions. This can be done and, what is more, is being done every day in modern business. With such methods, our so-called handicap disappears, and the limit of each man's opportunities lies only in his ability and capacity for development. He would have scarcely greater opportunity if his business were his in name, and then, too, it would no longer be financed for him.

Some men choose to operate under the policy that they are "hired" men. Such a one forgets that, to make a success, for himself or for his company, he must be a unit full of virile activity and stable productiveness; forgets that it is *his* company with which he is identified, and forgets that *he* is responsible to a degree for *its* achievements. The result is that he halts, while the organization passes on, although truly its advance might perhaps have been greater if he had been a "boosting" unit.

When a man is buying his own stamps, paying his own office rent, and hiring his own stenographers, he can be depended upon to keep all of his mental faculties and energies on duty to bring in real and increasing revenue. The "hired" employee of the big organization does not take this point of view. As a result he finds, to his regret, that he is truly in business with his company for himself, for the ultimate result is that he is relegated to the unimportant position, while the organization man receives the call.

Every successful concern of to-day must give good account of itself, and it can do so only through the co-operation of men having at heart true interest in its work. The days of the so-called independent man may be numbered, but the life of the organization man has just begun.

HARLAN A. PRATT

PRACTICAL INDUSTRIAL ILLUMINATION PROBLEMS

C. E. CLEWELL

ILLUMINATION problems include the selection of a type and size of lamp and accessories for given conditions; the determination of the number and arrangement of lamps for given floor areas, and the adaptation of the lighting units to certain requirements through the medium of a working drawing containing all the necessary information for the actual installation of a given system.

INSPECTING THE LOCATION

An essential element in the design of a lighting system is familiarity, either by inspection or otherwise, with the character of work or the service for which the illumination is intended. This, in large measure, determines the quantity of light necessary for satisfactory results, and in turn the number of lamps to be used. The location must be carefully measured, this fixing the width, length and height of the areas to be supplied with lamps. The position and size of columns, which divide the total floor space into a number of sub-divisions, should be observed because the bays determine, in a measure at least, the arrangement of wiring and control circuits. Attention should also be given to the kind of ceiling, that is, whether it is composed of plain wood without under girders or whether girders extend below, and also the color of ceiling and side walls—whether light or dark. It is obvious that the light reflected from the ceiling and walls may be a large factor in the resultant illumination on the reference plane. If the walls are very light, however, the glare caused by reflected light may be objectionable. It is also advisable to take into account the depth of girders and their spacing, not only on account of their influence on the wiring, but also on the permissible mounting height of the lamps which, if located too near the girders, may be obscured.

Supply Circuits—If the building to be equipped has been in use for some time and the new installation is to replace an older one, attention should be paid to the electric circuits available. This observation should include the capacity of wires, the voltage, its range of fluctuation, and whether the circuits are direct current or alternating current. The type of lamp is largely dependent upon the foregoing items, and the importance of ascertaining these various points is therefore evident. In Table I an enumeration is given of the supply circuits ordinarily used in various buildings, to-

gether with the type of lamp which may be used with each separate class of circuit. From this table it may be seen that certain lamps are adapted to only a few classes of circuits.

TABLE I.—TYPES OF LAMPS GENERALLY USED FOR THE VARIOUS CIRCUITS ORDINARILY FOUND IN PRACTICE

DIRECT-CURRENT CIRCUITS

Series	Multiple or Multiple Series		
	110 volts	220 volts	550 volts
Carbon Filament	Carbon Filament	Carbon Filament	Carbon Filament
Tungsten	Tungsten	Tungsten	Tungsten
Enclosed Carbon Arc	Enclosed Carbon Arc	Enclosed Carbon Arc	Enclosed Carbon Arc
Metallic Flame Arc	Metallic Flame Arc	Metallic Flame Arc	Metallic Flame Arc
Flame Carbon Arc	Flame Carbon Arc	Flame Carbon Arc	Flame Carbon Arc
	Nernst	Nernst	
	Cooper-Hewitt	Cooper-Hewitt	Cooper-Hewitt

ALTERNATING-CURRENT CIRCUITS

Series	Multiple			
	110 volts		220 volts	
	25 cycles	60 cycles	25 cycles	60 cycles
Carbon Filament	Carbon Filament	Carbon Filament	Carbon Filament	Carbon Filament
Tungsten	Tungsten	Tungsten	Tungsten	Tungsten
Enclosed Carbon Arc		Enclosed Carbon Arc		Enclosed Carbon Arc
Flame Carbon Arc		Flame Carbon Arc		Flame Carbon Arc
	Nernst	Nernst	Nernst	Nernst
		Cooper-Hewitt		Cooper-Hewitt

Space and Surrounding Conditions—In some factories belts occupy considerable space; others are free from obstructions; while

in still others dust and dirt are present in large quantities. Such conditions should all be taken into consideration when the original inspection of the location is made, as the type of lamp should be selected so as to be suitable to local conditions. The size and arrangement of windows has an important influence on the arrangement of control circuits and the general requirements of artificial illumination at those times of the day when it is mixed with natural light. The influence of some natural light when mixed with artificial light is a matter of fairly common knowledge, and while there is unquestionably a need for more artificial light on dark days than at night, there is some question as to whether there is an actual need for increasing the artificial light to meet these requirements. This necessity for additional artificial light should largely be determined on the basis of whether the artificial light is to be used mostly on dark days, or whether a night turn is also largely dependent upon the lighting facilities. In the latter case the determining feature will probably be the night turn, while in the former a slightly higher intensity of artificial light may be advisable than would be the case if it was to be used only at night.

SELECTION OF TYPE AND SIZE OF LAMP

The type of the lamp is largely influenced by the circuits available, by the space conditions, by the color of light desired, and lastly, regarding candle-power, by the size best adapted to the ceiling height in question. It has been found from experience that there is a certain relation between the mounting height and size of lamp, a satisfactory mounting height depending partly on the reduction of eye fatigue by the use of small lamps for low ceilings, and also partly on the shadow effect which varies with the ceiling height. Thus, from Fig. 1, it is apparent that, for a low ceiling, the lamps must be fairly close together to avoid unsatisfactory shadow effects, and therefore, the size of lamp should be small; while for higher ceilings, the spacing distance may be greater for the given shadow effect and the size of lamp correspondingly large. Fig. 1 is intended to serve merely as an indication of the results which are secured with different spacings and different sizes of lamps, and while it cannot be stated that the proper direction of the light is the only item associated with spacing and mounting conditions, it is obviously a large factor.

SPACING DISTANCES OF LAMPS

Spacing distances are in themselves a distinct feature in illumination calculations on account of the relation between spacing dis-

tance and mounting height which is necessary in order to provide light from a suitable number of different directions, in order to avoid annoying shadows. If the work in factory spaces is crowded, there should be a tendency to increase rather than diminish the number of lamps, thus bringing them closer together than otherwise. Thus, in a practical case, one must co-ordinate the various items of spacing distances, mounting height, and size of lamp in order to produce the best results, and judgment resulting from experience has possibly a greater bearing on the success in such cases

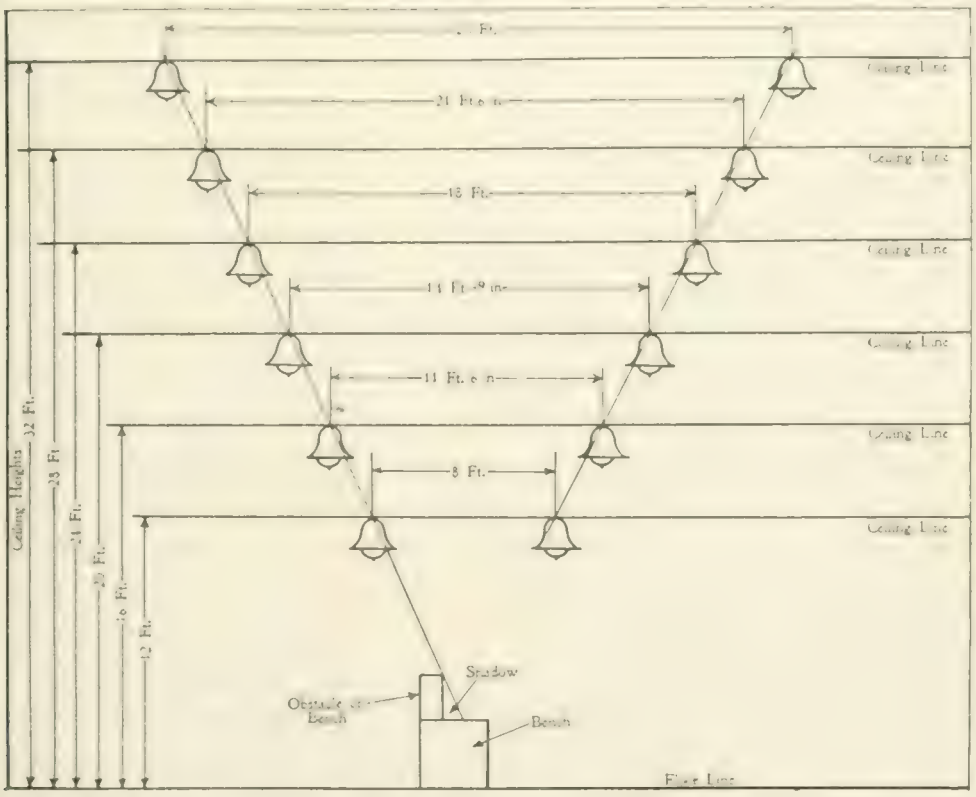


FIG. 1—SKETCH SHOWING EFFECT OF MOUNTING HEIGHT AND SPACING ON THE PRODUCTION OF GIVEN SHADOW EFFECTS

than the following rules. It is the endeavor, however, in the following paragraphs to make plain the methods which may be followed to secure certain desired results.

SELECTION OF REFLECTOR OR GLOBE

Reflectors should be used both to reduce the glare produced when looking directly at a bare lamp and to re-direct the light in the most effective manner. A reflector can practically always be secured which will furnish uniform illumination if it has been selected for the size of lamp in question and if the ratio of the spacing to the mounting height of the lamps is in accord with the

design of the reflector. It is evident, therefore, that the choice of the reflector should not be based solely on appearance, but that careful attention should be given to secure the results which the reflector has been designed to furnish.

Re-direction of Light—The distribution curve around a bare lamp, shown in Fig. 2, indicates that the light from the lamp is sent out in practically all directions. If the lamp is mounted fairly high, therefore, only part of the light will reach the work. The function of a reflector is to intercept the otherwise useless rays and to reflect them in a useful direction. It is, therefore, important, in lamps of the tungsten type, for example, for which a large variety of reflectors are available, either to adapt the reflector to the given spacing and mounting conditions of the lamp, or to adapt either the spacing or mounting conditions to the reflector chosen. It is usually best, however, to fix the spacing and mounting condition of the lamp, and then to decide on the reflector which is suited to this given condition.*

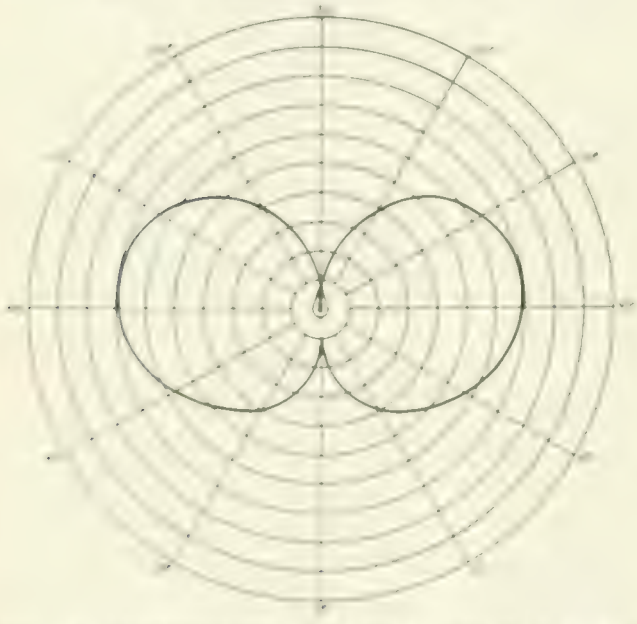


FIG. 2—DISTRIBUTION OF LIGHT ABOUT A TUNGSTEN LAMP NOT PROVIDED WITH REFLECTOR

Where no suitable reflectors are available, it is important to space the lamps sufficiently close together to insure approximate uniformity of the light. In other words, to eliminate the dark spaces which exist when lamps are spaced too far apart.

*Prismatic reflectors are designed for given ratios of spacing distance to mounting height. The Holophane Company furnishes a standard line of reflectors, called the Focusing, the Intensive and the Extensive. The Focusing type of reflector should be used where the ratio of spacing distance to mounting height is approximately 0.7; the Intensive type where this ratio is approximately 1.5, and the Extensive type where this ratio is 2. The design of reflectors to conform to these numerical values is entirely arbitrary, but has been followed in view of the fact that these values cover a large number of practical cases that arise. It is obvious that reflectors of other manufacture will furnish approximately similar results provided their distribution of light conforms in a general way to the distribution curves of the reflectors just mentioned.

MOUNTING HEIGHT

The details of building construction, or the interference of cranes, often limit the mounting height of lamps. As a general rule, lamps should be mounted high enough to be out of the direct line of vision in order to reduce glare. Where the ceiling is low, thus limiting the mounting height, small lamps should be used and proper protection afforded to the eyes by the use of reflectors. Sometimes it is necessary to furnish light to certain classes of work at an angle. This "side light" effect may be produced, either by mounting the lamps somewhat lower than would be the case were the elimination of glare the only consideration, or the lamps may be mounted at the best height and broadly distributing reflectors used.

THE WORKING DRAWING

After the determination of the spacing of the lamps, a plan view and elevation of the room should be drawn to scale, showing location of the lamps, girders, columns, conduit, switches, etc. The arrangement of switch circuits should be plainly indicated, and the specifications should include the type and size of lamps, reflectors and holders, conduit sizes and lengths, and other details necessary for the one who orders supplies.*

THE STEPS IN THE CALCULATION

It may be stated at the outset that in the method to be described the word "calculation" is perhaps somewhat misleading, as this method is largely made up of a series of steps in the matter of choice of various items based on tables, the calculations being mainly of a check nature. The idea, therefore, is rather to decide on a certain arrangement of lamps by means of the various steps, and then to check over these values in order to insure adequate intensity of light and uniform illumination on the working surface.

Type of Lamp—It has been shown that the type of lamp is largely dependent on the surroundings, circuits available, etc., and it may also be stated that the limits of candle-power of the different lamps of a given type largely determine whether this particular type can be used under given conditions. It would not, for example, be considered wise to use an arc lamp in a small office, and in like manner, it would be a decided disadvantage to use small tungsten lamps in high factory bays. If the space between floor and ceiling is crowded with belts, a lamp must be used which will be relatively

*For additional details see "The Installation of Industrial Lighting Systems" in the JOURNAL for June, 1912, p. 459.

unaffected by the dust and dirt particles, and which will not cast sharp shadows. Thus, for low ceilings, the mercury vapor lamp is somewhat more advantageous than those lamps which may be classed as point sources of light.

The first cost and operating expense is naturally an item to which considerable weight is given in choosing between one type of lamp and another; but the value of the resultant illumination with any given type of lamp is usually of much greater importance than any reasonable difference in first cost, or even in operating expense.

In general, therefore, the conditions of the space to be lighted, and the various types of lamps on the market, should be studied, after which, by a process of elimination, the choice will usually lie between perhaps two or three given types.

Size of Lamp—Experiment and experience largely determine the relation between mounting height and candle-power. Table II has been prepared to show in a general way the sizes of lamps which

TABLE II—RATIO OF MOUNTING HEIGHT TO SIZE OF LAMP

Mounting Height—Feet.	8 to 14	14 to 16	16 to 20	20 to 24
Size of Lamp—Candle-power.	48 to 80	80 to 125	80 to 200	200 to 450

are used for a variety of conditions, with particular reference to mounting heights. It is obvious that no exact ratio can exist between the size of lamp and its mounting height, but in general, the higher the ceiling, the larger should be the lamp. The determination of the proper size depends not only on the foregoing condition, but also on the class of work to be lighted. Thus, a location in which much side light is necessary requires smaller lamps closer together than a location in which uniform lighting on a plane is sufficient.

Spacing Distance—Although the size of lamp is largely determined by the mounting height and, furthermore, the necessary number of lamps is, in a measure, fixed by the choice of the size of each lamp, it is nevertheless a fact that a study of spacing distance is not only of interest but of profit as an entirely separate item. In general the spacing distance should be determined independently of the other factors, after which the size of the lamp and the spacing distance may be so correlated as to produce the desired result. Table III has been prepared from the average spacing dis-

tances which are employed in a large number of typical installations. As may be seen from this Table, there is no fixed rule governing the spacing distance for different ceiling heights. A reference to Fig. 1 would seem to indicate that there is such a rule; but it is believed that the wisest course is to follow those spacing distances which have approved themselves after considerable experiment and service, rather than to limit such a table to arbitrary values as determined by a diagram like that of Fig. 1.

The Mounting Height should be based on the condition of the location, especially in the matter of ceiling height, and is often governed by the presence of cranes or girders. Its determination should be based on the securing of uniform illumination, provided, of course, glare is not incurred by too low a mounting. Thus, if the spacing distance has been determined as well as the reflector, the mounting height is fixed by the ratio of spacing distance to mounting height for securing a uniform illumination result. On the other hand, if the type of reflector has not been selected, the mounting height may be chosen in order to reduce glare and to accommodate the clearance between cranes and ceiling or other conditions, and the reflector finally chosen on the basis of the ratio of the given spacing distance to mounting height.

TABLE III—RATIO OF MOUNTING HEIGHT TO SPACING DISTANCE

Mounting Height—Feet.	8	10	12	14	16	18	20	24
Spacing Distance—Feet.	8	8 to 10	8 to 12	8 to 14	8 to 16	10 to 16	10 to 18	10 to 20

DETERMINING THE INTENSITY AND UNIFORMITY

In the foregoing the purpose has been to describe in a general way the steps leading to the determination of the type and size of lamp and the spacing distance. It is obvious that no mathematical calculations have been employed thus far, but that values based on experience have been utilized. It would be unfortunate, however, to limit the treatment of the case to a determination of the foregoing items without suggesting some means for determining the actual intensity and uniformity secured. This would not be the case, of course, were it possible always to find in such tables a reference to conditions exactly similar to the conditions of the new

space to be lighted. Owing, however, to the great diversity of conditions, it is highly expedient to check over such results before they are approved.

In the following paragraphs some of the checking methods employed are explained:—

Efficiency—The first determination which must be made in such cases is that of the efficiency of the system. Thus, the ratio of the actual light received by the work to the total light generated by all the lamps in the system is defined, arbitrarily, as the efficiency of the lighting system. If, for example, the efficiency of the lighting system in a typical shop is assumed as twenty-five percent and if, furthermore, it is desired to secure an intensity of three-foot candles on the work, the total light flux, expressed in lumens, over the working surface must equal the product of the foot-candle intensity and the floor space expressed in square feet, and this product divided by the twenty five percent efficiency expresses the total light

TABLE IV—EFFICIENCY VALUES BASED ON AVERAGE PERFORMANCE OF TUNGSTEN LAMPS, USING GLASS REFLECTORS

Low office	27.1 percent
Fairly high factory office	27.4 percent
Low factory space	27.0 percent
Medium high factory space	30.8 percent
Fairly high factory space	29.1 percent

flux which the entire number of lamps in the system must develop in order to secure the given intensity on the work.*

After determining the type and size of lamp, and the spacing, the total light flux generated by all the lamps in the system may be multiplied by the efficiency and the total light flux effective on the work thus determined. This result may then be divided by the floor space in square feet and the result will be the intensity in foot-candles which may be expected provided the efficiency has been properly chosen.

The only difficulty in using this method is to determine the efficiency which may be expected for the given conditions. In Table IV a number of efficiency values which have been obtained under actual conditions are shown. It should be remembered that these values change with every condition of ceiling and wall reflection, and also with the accumulations of dust or dirt on reflectors

*The total flux in lumens from any type of lamp can be obtained from the manufacturer's data sheets, which are supplied by any lamp manufacturer on application. For further details with regard to this method, see "Methods of Calculating Illumination" in the JOURNAL for June, 1912, p. 473.

and globes. It has been the purpose, therefore, in this table to represent average efficiency values throughout the service of given industrial installations, rather than the initial values which are found when the system is new and clean.

Point Addition—This term refers to the calculation of the quantity of light on the working surface at a given point produced by the various lamps which are effective in lighting this point. This may be done by using the distribution curve of the lamp in question. In order to make this calculation plain, Fig. 3 is shown. In this diagram it is apparent that the downward intensity at any given point may easily be calculated provided the candle-power of the lamp in the direction of the point is known, as well as the angle between this direction and the vertical. It is obvious that this calculation, to be of service, must be made for each different direction in which the light rays from the various lamps reach the point under consideration. It is, therefore, a problem of some length to calculate the illumination at a given point on a floor space, where a large number of lamps fairly close together are used.

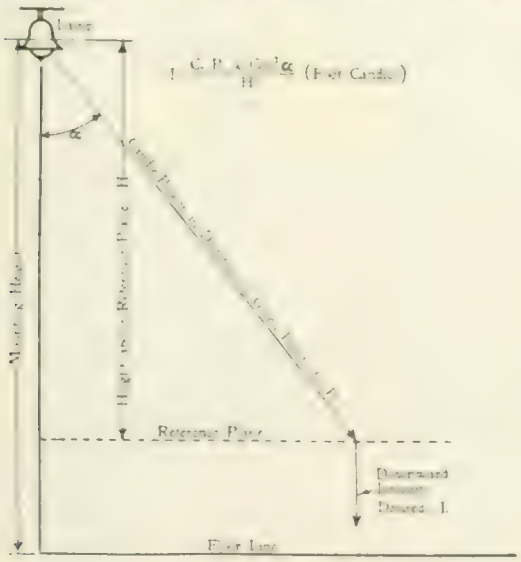


FIG. 3.—DIAGRAM ON WHICH THE POINT ADDITION CHECK MAY BE BASED

Point Addition Rule—A simple and practical method was developed several years ago for the point addition check by the use of a rule as shown in Fig. 4. On this rule are indicated the calculated values of the downward illumination intensity at various distances from a point directly beneath the lamp. If the divisions on the rule are drawn to the same scale as the drawing on which it is to be used, the rule may be used to indicate at a glance the downward intensities at any given point from a number of lamps which contribute light to the point. The method is further amplified in the practical problem which is treated later. Other adaptations of this principle have been made so as to make the rule applicable for all mounting heights for a given type of lamp and reflector.

While it has been suggested at different times that the point addition method may be used as a means for calculating the ar-

rangement of lamps, it is considered better to use this means for checking the arrangement of the lamps as previously selected rather than for a primary calculation. If the question of size of lamp and spacing is left to what may be called a hit or miss scheme, it is quite possible that the resulting arrangement of lamps may not result in satisfactory illumination results.

PRACTICAL PROBLEM

Proposition—As an example of the foregoing items, a low factory space is selected, twelve feet in height, with columns and girders so arranged that the bays have dimensions of 16 to 40 feet. The clearance between crane and ceiling is 12 inches; the ceiling is of wood with no under girders; ceiling and surroundings are very dark; there are no walls to this factory space; the illumination is for lathe and assembly work, with dark surfaces; 110 volt, 25 cycle alternating-current circuits available.

Required—An arrangement of lamps which will furnish adequate illumination on a working surface approximately three feet above the floor without the use of individual lamps; a suitable

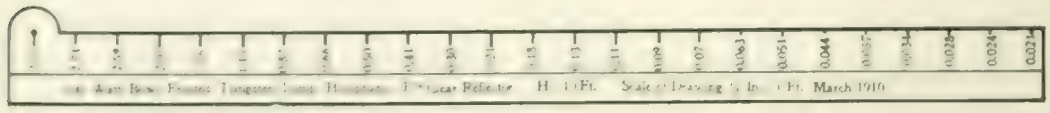


FIG. 4—POINT ADDITION RULE ADAPTED FOR 100 WATT TUNGSTEN LAMPS

control arrangement which is flexible and by which lamps may be turned off over parts of the floor where not required; and the total number of lamps for twenty similar bays.

Type and Size of Lamp—By reference to Table II it is seen that, for a 12 foot ceiling, lamps of approximately 80 candle-power have been found satisfactory. The surroundings being dark, a unit should be used from which some light is transmitted to the ceiling on account of the added cheerfulness this produces. A reference to Table I shows that for 110 volt, 25 cycle circuits, lamps of the tungsten type may be used, and this fact, together with the candle-power best adapted to the ceiling height in question, makes the selection of a tungsten lamp desirable. It is in fact practically essential to use tungsten lamps in this particular case on account of the small clearance between crane and ceiling. Even were the crane clearance larger, it would be difficult, with lamps of higher candle-power than shown in this table, to produce satisfactory illumination as far as uniformity is concerned without using an excessive number of lamps.

Spacing Distance—A diagram of one of the bays in this location, with dimensions 16 by 40 feet, may now be made, on which the lamps are to be located tentatively as shown in Fig. 5. A reference to Table III shows that an average spacing distance for a 12 foot ceiling is from 8 to 12 feet, and 8 feet will be chosen as the spacing distance in a direction parallel to the length of the aisle, while a spacing distance of 10 feet in a direction at right angles to the length of the aisle makes the arrangement of lamps symmetrical with respect to the width. These spacing distances are chosen, moreover, because they conform to the average shown in Table III.

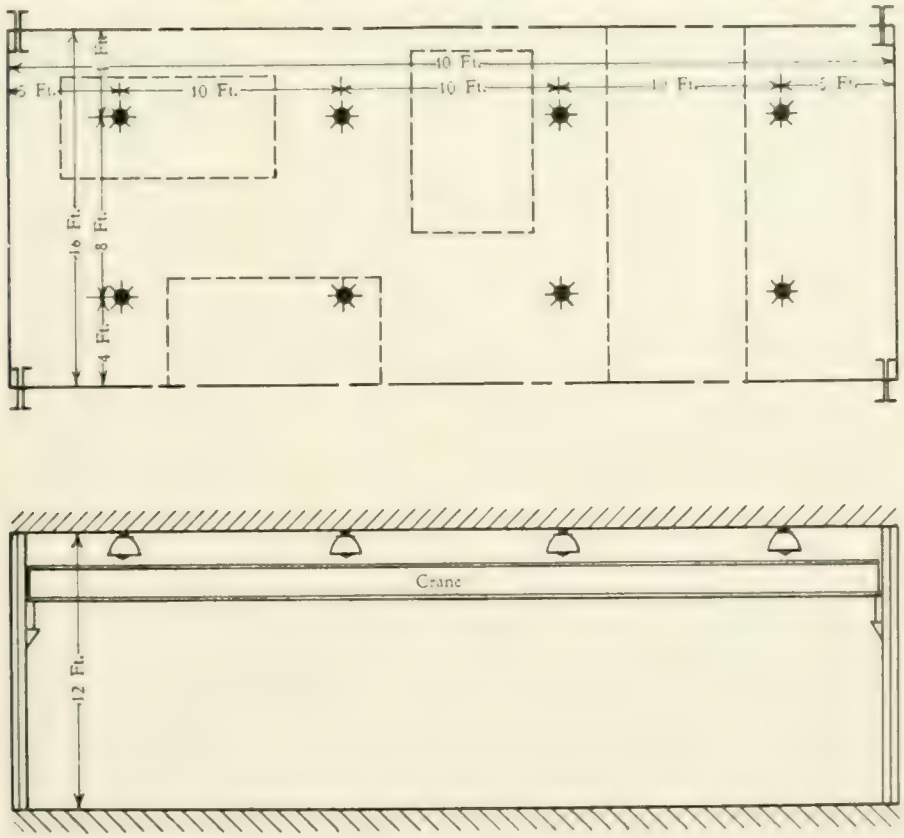


FIG. 5—PLAN AND ELEVATION OF ONE BAY OF THE GIVEN LOCATION

Mounting Height—In this case the mounting height is determined by the clearance between crane and ceiling. On account of the low ceiling it is advisable to mount the lamps as high as possible to avoid glare. Due to the limitations, therefore, a mounting height of 11 feet 6 inches is chosen.

Checking the Result—It now remains to check the intensity and uniformity which will result from the foregoing. With the spacing distance of 8 by 10 feet, one 100 watt tungsten lamp illuminates a floor space of 80 feet. A reference to Table IV shows, that under the conditions as explained for this factory space, an effi-

ciency of thirty percent is apt to result. A 100 watt tungsten lamp furnishes 830* lumens of light and with the assumed efficiency of thirty percent the total number of lumens produced on the 80 square feet illuminated by one lamp will be approximately 250, which, divided by the 80 square feet, results in an equivalent of three foot-candles. A reference to Table V shows that this intensity should be adequate for this class of work based on other practical installations.

Point Addition—The diagram shown in Fig. 6, which contains six of the twenty bays drawn up to a scale of one-half inch to a foot, permits of the use of point addition check. The rule is placed on the drawing as shown and turned about the point *A* so as to determine by inspection the intensity at this point produced by all the lamps of the system which contribute to the point. Subsequently the rule is placed at point *B* and the total intensity at this point determined in like manner. The illumination at a series of points as shown, namely, *A*, *B*, *C*, *D*, *E*, *F*, *G* and *H*, produced by the various

TABLE V—EXAMPLES OF AVERAGE INTENSITY VALUES BASED ON SUCCESSFUL LIGHTING SYSTEMS

Factory work (rough)	3.0 foot candles
Factory work (close)	4.0 foot candles
Machine work (close)	4.0 foot candles
Storage	1.0 foot candles

lamps which contribute light to each one of the points, shows that the average resulting illumination will be in the neighborhood of three foot-candles. The addition of the light at these various points also shows that the intensity at each of the points should provide a fairly uniform illumination so that the latter check covers not only the intensities of light at the various points, but also shows the uniformity.

Number of Lamps and Switch Control—On the basis of the foregoing calculations, a total of 160 one hundred watt tungsten lamps will be required for the twenty bays. A flexible method of switch control is shown in Fig. 6 where the lamps controlled from a single switch are surrounded by dotted lines.

The Actual Result—It is of interest to note that with the use of 100 watt tungsten lamps mounted 11 feet 6 inches above the floor, with a spacing of 8 by 10 feet, as determined by the foregoing calculations, the intensity, as recorded from measurements, was on the average, two and one-half foot-candles, and the effi-

*For data refer to published tables by lamp manufacturers

ciency about 24 percent. The conditions thus found in this case are somewhat lower than those which might have been expected from the calculations, but this fact is largely accounted for by the very dark surorundings, and thus show most forcibly the precautions which should always be taken to allow for surrounding conditions.

PRACTICAL CONSIDERATIONS

From the foregoing notes it might be inferred that the calculation for lighting systems is not only cumbersome and complex, but largely devoid of system. It should be stated, however, that the fundamental idea has been to show the practical reasoning which should be followed in cases of this kind. It is not the intention to formulate a set of rules, but rather to describe in as brief a

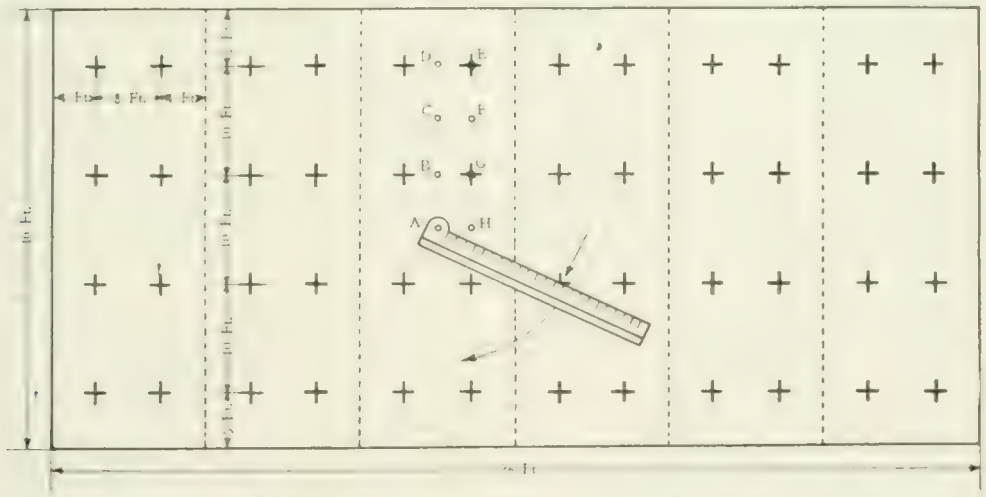


FIG. 6—DIAGRAM SHOWING HOW POINT ADDITION RULE MAY BE APPLIED TO A WORKING DRAWING

manner as possible the methods which are being employed in everyday calculations of practical lighting systems.

In many cases where the refinements here described cannot conveniently be considered there are, in general, a limited number of groups of reflectors that may be used, for tungsten lamps for example, and the determination of the group best adapted to given conditions is fairly simple. The resultant illumination by the selection of a certain type of reflector, therefore, if the simple data givn by the reflector companies are followed, will produce a fairly satisfactory result, even without any great amount of calculation, although where extensive work is to be performed it is highly desirable to do away as much as possible with rules and formulæ as generalities, and to use them rather in conjunction with the methods herein set forth, these various items being used as guides to the intelligent application of such scientific information.

SAFEGUARDING FACTORY TOOLS AND EQUIPMENT

D. C. PUTNEY

THE preservation of life and limb of the workmen employed in factories and workshops is one of the most vital issues in our industrial operations. Until very recently, the safeguarding of machines and other equipment in manufacturing establishments was largely ignored, the result being unnecessary loss of life and limb among employes. It is pleasing to note, however, that without waiting for the passing of laws by legislatures, many of the more progressive employers of labor are spending large sums of money in the devising and applying of safeguards and other means of accident prevention. The fact remains, nevertheless, that the proper place to apply safeguards for tools is at the workshop of the tool builder, and the time will soon come when the tool maker who does not offer completely guarded tools will be obliged to fall in line or get out of the business.

In the developing of safeguards, the safety appliance engineer has to be guided very much by the condition of the machine to be safeguarded, for, in a great number of cases, the guards have to be built to suit the tool requirements. Another consideration is the question of cost, which always comes up when the matter of safeguarding is concerned. It must be borne in mind that all accidents cannot be considered as preventable, and that some which may be avoided do not come within the province of the safety appliance engineer, but are directly under the control of the workmen themselves. There is no doubt, however, but that by the cultivation of greater care and mechanical precautions, the sacrifice of life and limb can be greatly reduced. It is also a fact that the average workman, when he knows that danger has been practically eliminated, becomes careless and takes chances he never would dream of under old conditions and consequently often meets with injury that he could have avoided. There is in all manufacturing a certain element of danger that cannot be provided for by any safety device and from which the workman has to guard himself.

Gears may be so located that there does not appear to be any possibility of danger, but something may happen that brings about an unusual condition, and a man may get caught at a point which was considered safe. It is necessary not only to cover up all gears at the mesh points, but those having arms should be covered.

The installation of electrical apparatus has not been given the same close attention as some other classes of machines, and some

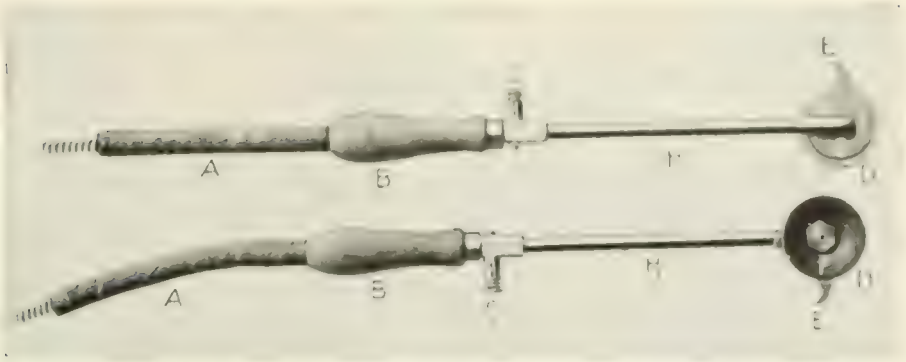
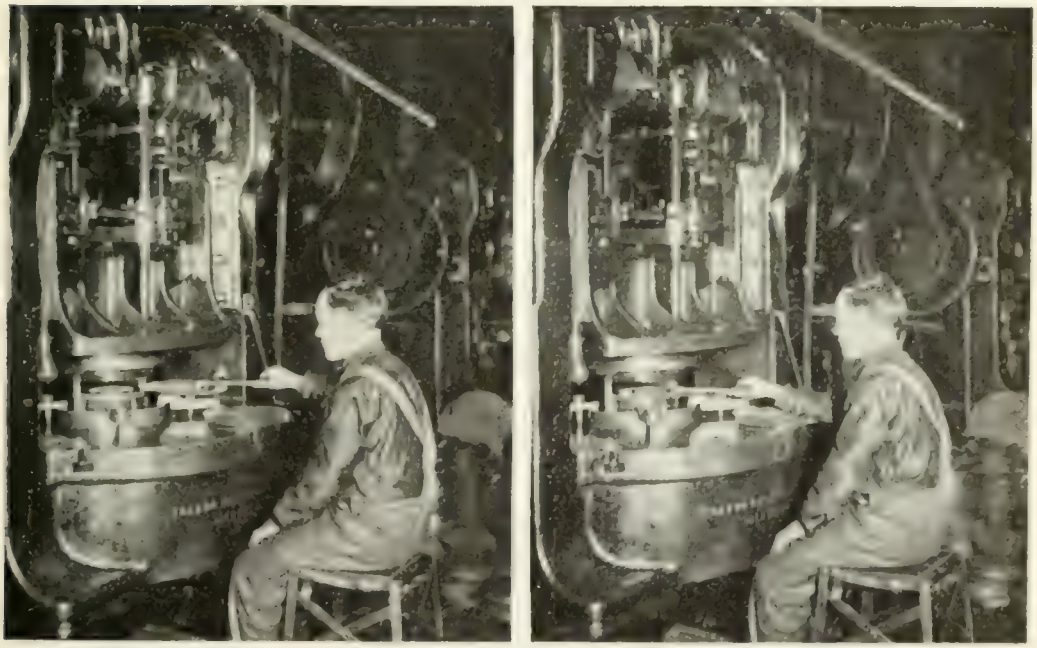


FIG. 1—DEVICE FOR HANDLING PUNCHINGS



FIGS. 2 AND 3—ILLUSTRATING DEVICE IN USE

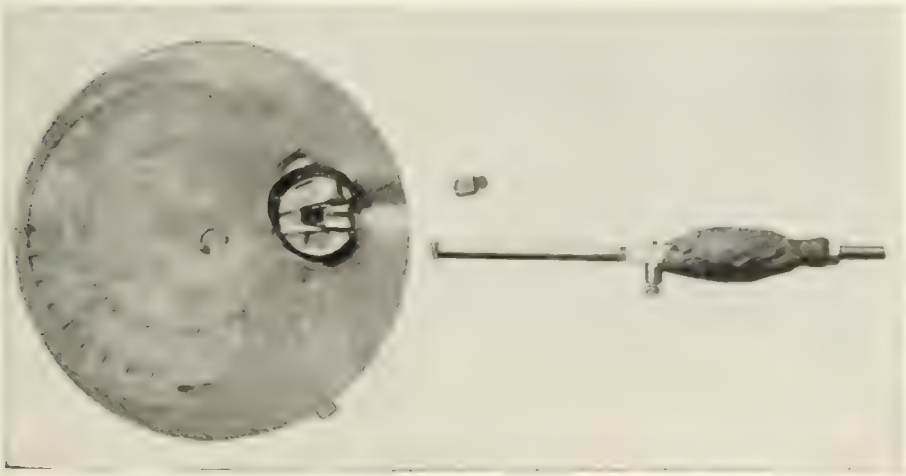


FIG. 4—RESULT OF AN ACCIDENT
The hand of the operator not involved.

controversy has arisen as to what should be the unit of voltage that might be looked upon as safe. Such apparatus should all be treated alike, whether it operates at 110 or 110 000 volts. Cases where men have been killed on 110 volts are on record. But, what is more important, a man may come in contact with a circuit which is not sufficient in itself to inflict injury but which may cause him to make a sudden movement which brings him in contact with danger from another source. There should be no dividing line between "safe" and "unsafe"—*make it all safe.*

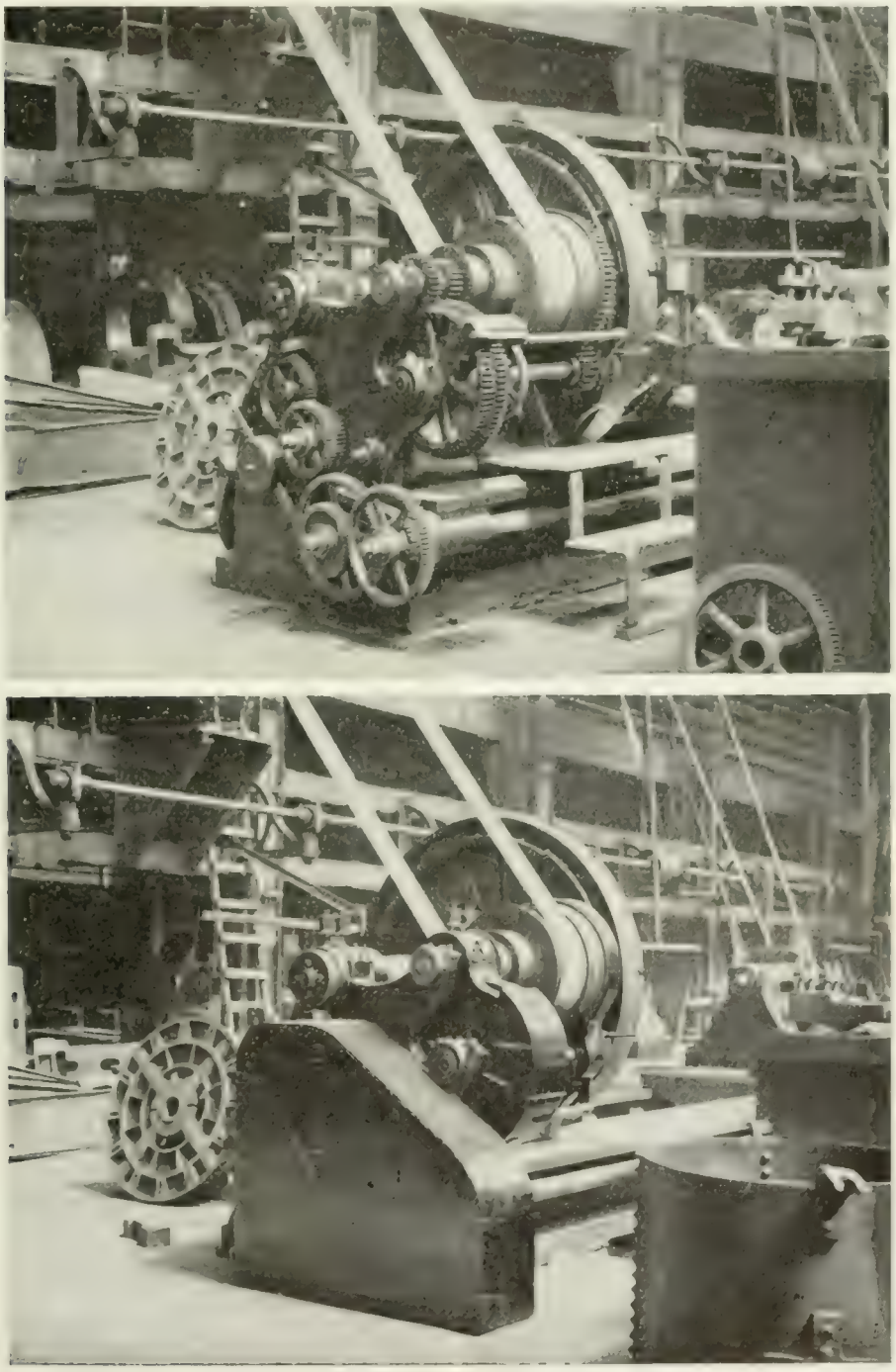
There are numerous other details that might be taken up if space permitted, such as cranes, line shafting, belts, ladders, etc. But as the matter of safeguarding receives the general attention which it deserves, obvious preventive measures present themselves to the mind of the shop manager and the workmen, as well.

The attitude of the workmen in relation to safeguarding is an important matter. The great bulk of the men look upon such measures with favor and appreciate the fact that something is being done to protect them; but there are others who have another point of view, thinking that they are going to be harmed financially or curtailed in their ability to produce; and it may be remarked that such complaints do not come from the unintelligent foreigners but generally from some suspicious American-born workman. However, this feeling will eventually disappear.

The installation of safeguarding appliances and safety devices is being carried on very extensively and with most satisfactory results in the various works of the Westinghouse Electric & Mfg. Company at East Pittsburgh, as exemplified in the accompanying illustrations. Punch presses probably rank as high as any other class of machinery in frequency of accident, the injury being in many cases severe. Automatic dies, hoppers, push slide feeds, automatic bar guards, etc., have done much to lessen the dangers from this cause. There is in use in the punch shops of this company, a simple device gotten up by one of the inspectors, which can be applied and operated at very little cost, the source of power for a group of punch presses being obtained from a vacuum pump connected to a pipe line. The extreme simplicity of the device and its operation are illustrated in Figs. 1, 2 and 3. It does away entirely with any necessity for the operator getting dangerously near the dies.

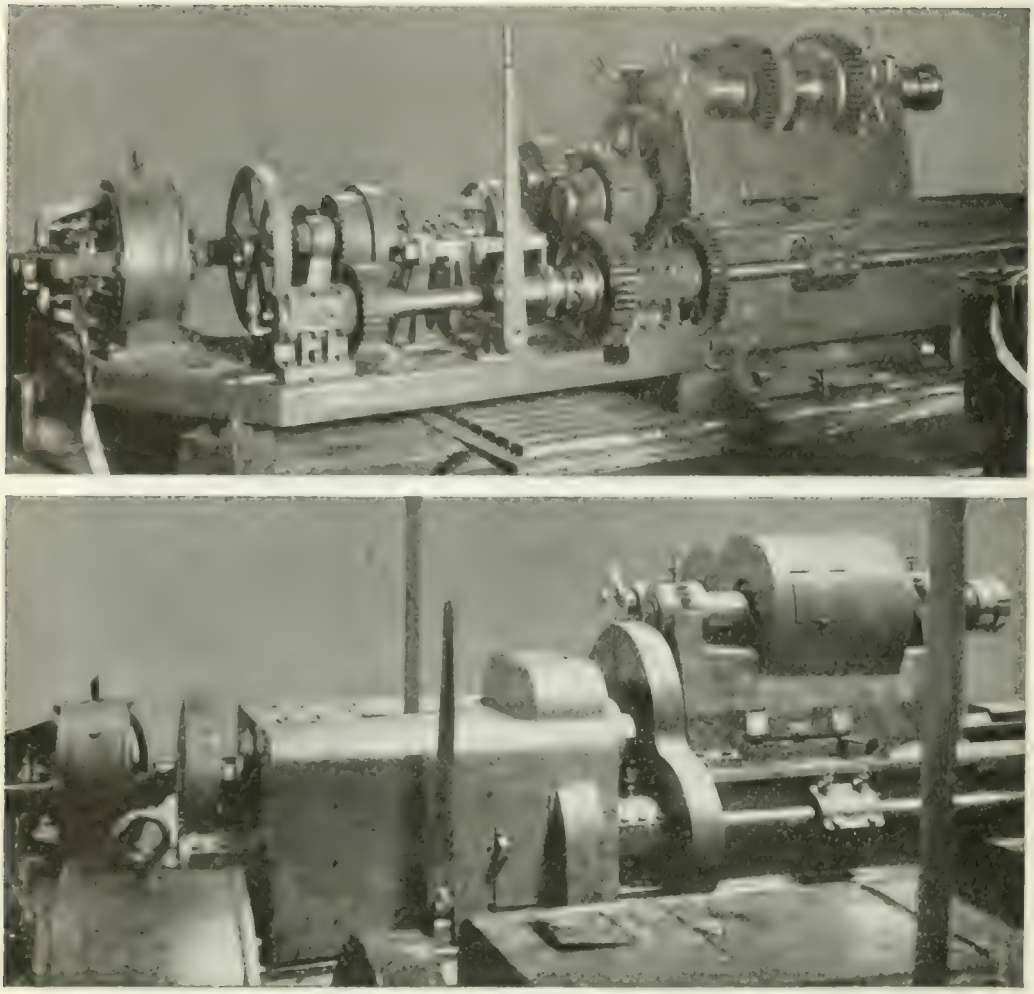
Top and bottom views of this device are shown in Fig. 1. *A* is a rubber hose connecting with the vacuum pipe line; *B* is the handle; *C* is a thumb valve controlling the power; *D* is a leather cup or sucker which adheres to the metal when the air is exhausted; *E* is

a steel picker to lift the scrap out from under die after the operation; *F* is the air exhaust hole connecting with tube *H*. This tube *H* can be made any length to suit the requirements of the application.

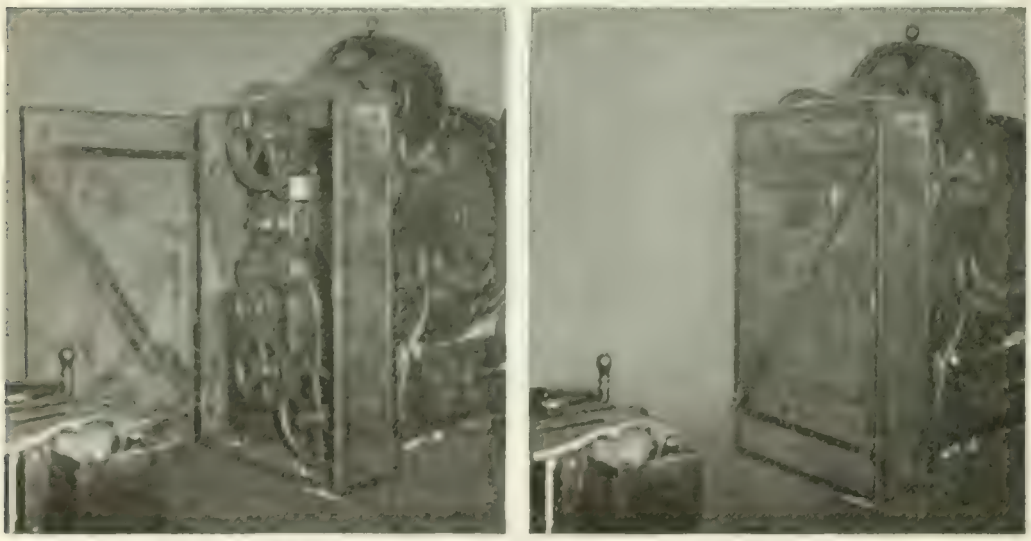


FIGS. 5 AND 6—RUNNING GEAR OF LATHE EXPOSED AND COVERED

In Fig. 2 the sheet steel disc *A* is shown adhering to the device while being conveyed to the machine. The thumb of the operator is on the valve, which opens the connection with the pipe line *B*. In Fig. 3, the die has done its work and the operator is picking the scrap



FIGS. 7 AND 8—RUNNING GEAR OF MOTOR-DRIVEN WINDING MACHINE EXPOSED AND COVERED



FIGS. 9 AND 10—GEARING ON MACHINE PROTECTED BY A SIMPLE WIRE CAGE, AND MADE ACCESSIBLE BY SWINGING DOOR

out of the punch, the thumb being removed from the valve. The effect on one of the devices which was accidentally caught under a die and crushed is illustrated in Fig. 4. The punch operator missed

his usual rythmical motion with the result shown. He procured another device and went ahead with his work, neither the operator nor die being injured. Under the old conditions, this might have resulted in the loss of a man's hand. It is an interesting and significant fact that the use of this safeguard has also resulted in an increase in production—in many cases as much as 20 percent—as the operator soon gets to be very expert in handling the device so that he can feed and clear his press much quicker than by hand. He also knows he is safe, and this is an incentive to quick work.

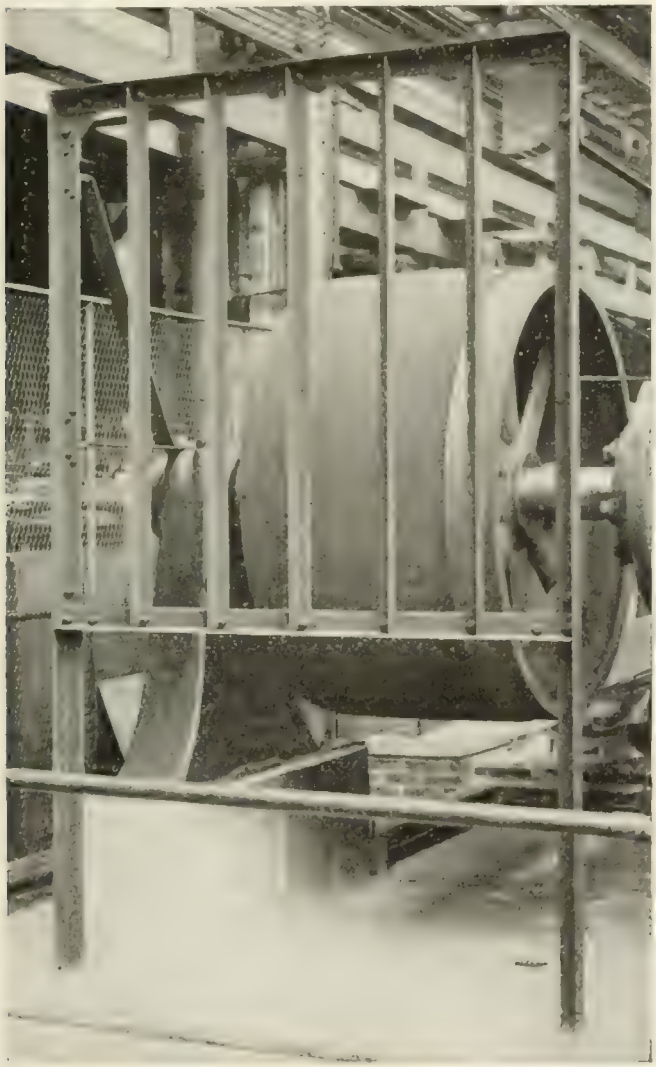


FIG. 11—BARRIER AND FENCE ERECTED AS GUARD AGAINST ACCIDENT IN CASE OF BREAKING OF HEAVY BELT

A large lathe with exposed gears, which stood in dangerous proximity to a passage way where hundreds of people pass to and fro every day, is shown in Fig. 5. The same machine is shown in Fig. 6 after receiving attention at the hands of the safety appliance engineer and being dressed in "an up-to-date suit of sheet steel clothing." It will be observed that the door on the large gear case at the end of the lathe opens up in three sections, allowing free access to change the gears, thus doing away with the necessity of removing the gear case. The bottom of the case is constructed to form an oil drip pan. One of the small doors fitted with spring hinges to admit oiling of the gears, is shown at *A*.

A type of special winding machine is shown in Fig. 7 as it stood in the machine department after being tested and before being dismantled and transferred for final erection. The same machine is

shown in Fig. 8 after being erected and put in operation, indicating the completeness of the safeguarding. Note the number of spring hinged doors to permit oiling at every point.

An example of a different type of safeguard with door open to permit changing of gears and oiling is shown in Figs. 9 and 10. The gear case door is kept closed when the machine is running.

Many types of guards have been erected in front of belt pulleys where belts are traveling at high speed, to prevent accident in case the belt should break. One arrangement is represented in Fig. 11. It consists of a heavy angle iron frame well stayed and set in cement, and to insure further safety, an iron pipe fence is erected a considerable distance back.



FIG. 12—GLASS EYE SHIELD WITH ADJUSTABLE METAL FRAME FOR USE WITH EMERY WHEELS

A type of eye shield fitted to emery wheels is illustrated in Fig. 12. The construction is such that, in case of breakage, a new glass can easily be placed in the slotted frame by the workman. A small stock of glass plates cut to size is kept at the machines for this purpose. Some time ago an endeavor was made to introduce the wearing of special glasses by the men using emery wheels, but with scant success, as the majority tried in every way to evade using them. Some men wear them, but they are few compared to the total number affected. A device such as that shown circumvents this trouble and provides the desired protection. The foregoing illustrations from one particular type of manufacturing plant, while giving only a general idea of what is being done in safeguarding employes against accidents and injuries, may be taken as typical of what is being done in many industries by the more progressive manufacturers. The increased assurance of workmen operating apparatus which they know to be well safeguarded has a favorable effect on their efficiency of production, which of itself may go a long way towards reimbursing the manufacturer for the added expense incident to the installation of safety devices.

IMPROVING POWER-FACTOR OF AN INDUSTRIAL LOAD

E. R. SPENCER

AN interesting example of power-factor correction is to be found at the pipe and tube plant of the Spang-Chalfant Company, at Etna, a suburb of Pittsburgh, Pennsylvania. There are two distinct mills, one about 4 500 feet and the other about 800 feet from the power house. The product of these mills is lap and butt welded pipe and tubing. This plant is especially interesting to electrical and steel mill engineers because of the fact that all rolling, welding and auxiliary machinery is equipped with motor drive. The load on individual motors throughout the mills is necessarily more or less intermittent, as in most cases the motors run on partial loads for relatively long periods.* For the greater part, 220 volt induction motors are used. The power-factor of the load at either plant would average less than 50 percent were it not that provision is made for obviating low power-factor conditions by the use of synchronous motor-generators operated to give power-factor correction.

It may be mentioned incidentally, that the operating conditions in this plant have been materially improved by giving considerable attention to the question of suiting the capacity of motors as installed to the actual load requirements throughout the plant. Of course there is a limit to the improvement in power-factor which may be secured in this way as each motor must have sufficient capacity to deliver the torque required to handle the peak loads without failure, as such peak loads ordinarily occur at critical stages in the cycle of operations. By thus carefully investigating the relation between load requirements and motor capacities, the operating efficiency of industrial power systems may often be materially increased without considering power-factor correction by synchronous motors.

The results that have been effected in the direction of increased power-factor are of particular interest because the synchronous motor-generator sets are used to generate direct-current power at 220 volts, and this power is used for supplying a portion

*Graphic meter records showing the characteristics of these various loads are given in an article on "Power Requirements of a Steel Tube Mill" in the JOURNAL for Dec., 1911, p. 1051.

of the motor load, notably in cases where direct-current motors appear to possess characteristics which suit them more particularly to the requirements of the service. Thus, with a double current source of power supply the system is operated at probably much higher economy than would otherwise be possible. The details of this double current system are being developed gradually.

Before the installation of the motor-generator sets the conditions were as follows:—The actual average power-factor of the upper mill was approximately 48 percent. In the lower mill, the power-factor was somewhat higher, about 54 percent, due to the effect of a 200 horse-power induction motor-generator set, uniformly loaded up to its full capacity and accordingly operating at a high power-factor. Under these conditions the power house generators carried a load having about 52 percent average power-factor. This led to the installation of a synchronous motor-generator set in the sub-station at this lower mill, and although the direct-current load is not large, the synchronous motor is of sufficient capacity so that it may be operated at a power-factor which will give a resultant load power-factor closely approaching unity; a condition favorable alike to the generators and the 2 400 volt transmission line supplying power to the sub-station.

Power is supplied directly at 220 volts to the upper mill, as it is only 800 feet from the power house. This load at 48 percent power-factor combined with the load of the lower mill at unity power-factor resulted in a power-factor at the generators varying from 70 to 80 percent, depending on the actual load conditions. It was found upon further investigating the problem that it would be possible by replacing a direct-current, engine-driven generator by a synchronous motor-generator set, not only to supply the direct-current power required at the upper mill, but to confine the prime movers in the power house to the four alternating-current units installed and, through power-factor correction by over-excitation of the synchronous motor, so to improve the load conditions that the available kilowatt capacity of the generators would be materially increased. At the time, this motor-generator set could not conveniently be located at the mill and it was, therefore, placed in the power house. This set consists of a 1 000 k.v.a., three-phase, 30 cycle, 220 volt, 600 r.p.m. synchronous motor direct-connected to a 400 kw, 220 volt, direct-current, compound-wound generator. A motor capacity was selected which would allow of the use of a considerable portion of its total k.v.a. for purely cor-

rective effect by increased field excitation. Thus, the power-factor of the total load on the generators was raised to between 97 and 100 percent.

As a result of the improved conditions of loading on the system, which renders the total k.v.a. capacity of the generators available for supplying useful power, it is ordinarily possible to hold at least one spare unit for use in emergency or at periods of peak load as they may occur. This means then that the number of operating prime movers in this power house is reduced from five to three, and sometimes to two units. Ultimately, the motor-generator set now in the power house will be installed in a more

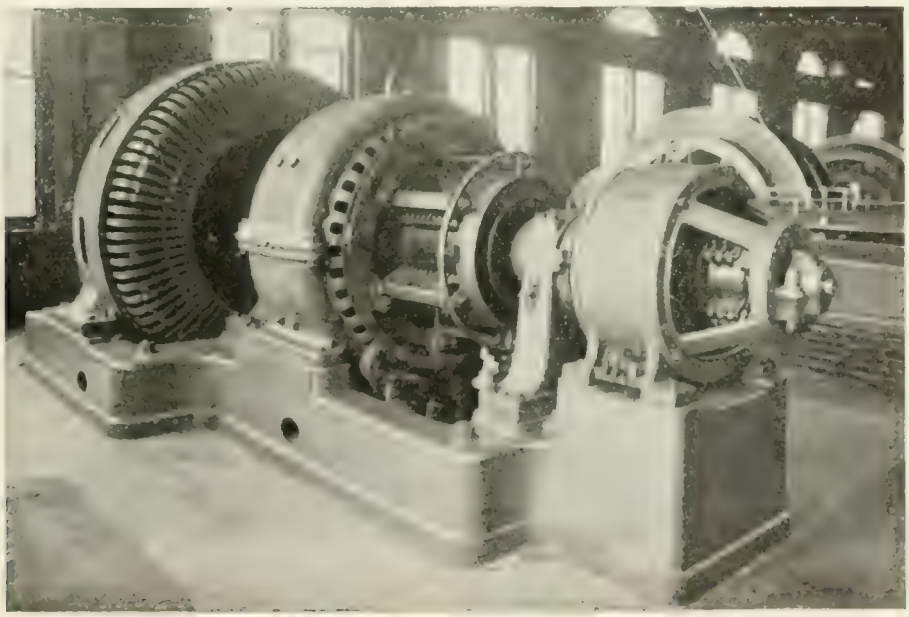


FIG. 1—SYNCHRONOUS MOTOR-GENERATOR SET EMPLOYED FOR SIMULTANEOUSLY SUPPLYING DIRECT-CURRENT POWER AND CORRECTING FOR LOW POWER-FACTOR

Installed in mills of the Spang-Chalfant Company, Pittsburgh

central location in the upper mill so that it will not only be at the delivery end of the direct-current feeders for this plant but will also provide maximum power-factor correction for the transmission line as well as the generating equipment.

Under existing conditions the synchronous motor of this set is usually operated at a leading power-factor near 20 percent. At present the actual direct-current load on the generator is small, which, with practically full k.v.a. input to the motor, accounts for the low leading power-factor. When the set is moved to its ultimate location out in the mill, the increased power-factor of the load that the transmission line will be called upon to carry will render a large amount of cable, now required in the transmission

of the extra current due to the poor power-factor in the mill, available for carrying other useful load, and thus a further economy will be effected, which will be especially important when there has been a material increase in the load requirements of this mill.

A view of the motor-generator set from the exciter end is shown in Fig. 1. The exciter is direct-connected and overhung on the shaft beyond the generator outboard bearing. A view from the synchronous motor end is shown in Fig. 2. It is inter-

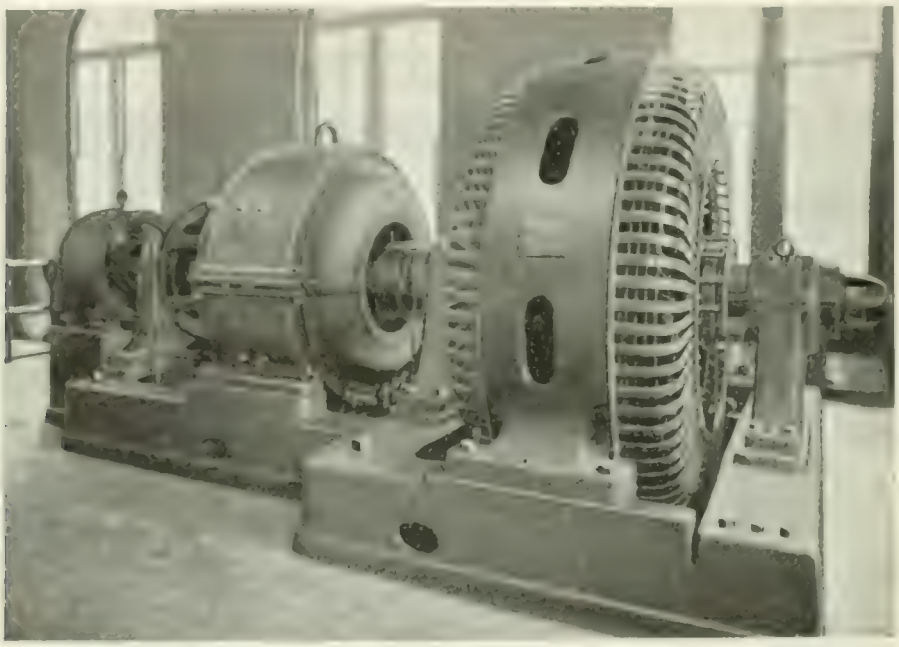


FIG. 2—VIEW FROM MOTOR END OF SYNCHRONOUS MOTOR-GENERATOR SET
Spang-Chalfant mills.

esting to note the use of an air-directing end bell on the direct-current generator. It has been found that where two electrical machines are mounted on the same shaft, as in a motor-generator set, there is a tendency for the air to "pocket" in the space between the machines and to whirl around with the rotors rather than discharge through the frames and cool the machines. A ventilating end bell like that shown in Fig. 2 serves to direct the ventilating air through the generator and corrects the tendency toward air pocketing.

DETERMINATION OF POLARITY OF TRANSFORMERS FOR PARALLEL OPERATION*

W. M. McCONAHEY

WHEN two or more transformers are to be operated in parallel or in banks on a polyphase circuit, it is necessary to know their polarity in order to connect them properly. Polarity is a term used to express the phase relation between the primary and secondary voltages of a transformer, as measured at the outlet terminals. If all of the transformers are alike, they may have the same polarity, but if some of them are of different design or were made by different manufacturers, their polarity may be different.

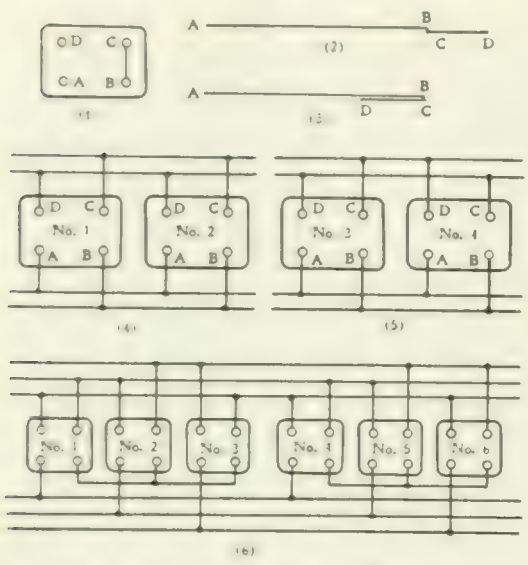
The polarity of a single-phase transformer is very easily determined. In Fig. 1, let *A* and *B* be the high-tension terminals and *C* and *D* the low-tension terminals. Connect *B* and *C* together and impress some convenient voltage across either *A*-*B* or *C*-*D*. Then measure voltages *A*-*B*, *C*-*D* and *A*-*D*. Now, since the transformer is single-phase, the voltages considered in the directions from *A* to *B* and *D* to *C* must either be in phase or in opposition, that is, 180 degrees out of phase. If the voltage across *A*-*D* is the sum of those across *A*-*B* and *C*-*D*, the phase relation is shown in the diagram, Fig. 2, and the polarity may be called *positive*. If the voltage across *A*-*D* is the difference between *A*-*B* and *C*-*D*, the phase relation is shown in the diagram, Fig. 3, and the polarity is *negative*.

If two single-phase transformers, both having positive polarity or both having negative polarity, are to be operated in parallel, they should be connected together in the manner shown in Fig. 4. But if one has positive polarity and the other negative, then they should be connected together as shown in Fig. 5. This will be understood by reference to Figs. 2 and 3. Counting the voltages from left to right as being in the positive direction, *a* to *b* and *c* to *d* (the voltages corresponding to the windings indicated in Fig. 2) are in the positive direction for positive polarity, while for negative polarity (Fig. 3) *a* to *b* is positive and *c* to *d* negative. If, however, the connections of *c* and *d* are reversed, *d* to *c* is in the

*Revised by the author from part of a paper presented at the Seattle Convention of the National Electric Light Association, June, 1912.

positive direction. If, therefore, a single-phase transformer of negative polarity is to be connected in parallel with one of positive polarity, it is necessary to reverse the connections of either the high-tension winding or the low-tension winding of one of the two transformers as shown in Fig. 5.

Single-phase transformers connected in banks on three-phase circuits are simpler to deal with than three-phase transformers. Three-phase polarity tests are much more complicated than single-phase, because there are a large number of possible combinations, some of which can be made to operate together while others cannot.



FIGS. 1, 2, 3, 4, 5 AND 6—ILLUSTRATING "POLARITY" OF TRANSFORMERS

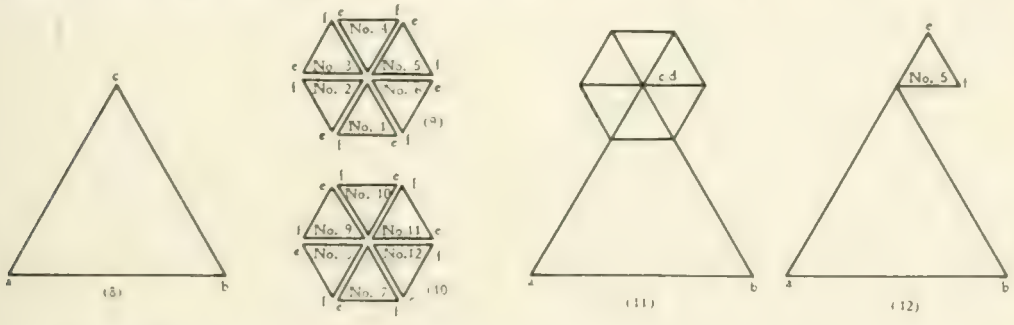
A standard star-delta connection with six single-phase transformers in two parallel banks is shown in Fig. 6, the polarity of *No. 6* being the reverse of that of the other five. If the polarity of all six transformers were the same, *No. 6* would be connected in a manner similar to *No. 3* instead of having the connections of one winding reversed. If the polarity of all the transformers is the same, all banks should be connected to the line in an exactly similar manner. It is possible to connect one bank differently from the others and still secure parallel operation, but this is not advisable, because it is liable to lead to confusion and trouble. It is best to adopt one scheme of connection and adhere to it.



FIG. 7

In a three-phase transformer the measurements necessary to determine the polarity are made in a manner similar to those for single-phase. In Fig. 7, let *A*, *B* and *C* be the high-tension terminals and *D*, *E* and *F* the low-tension terminals of a three-phase transformer. Connect *C* and *D* together and impress any convenient three-phase voltage across either the high-tension or low-tension terminals. Then measure voltages *A-B*, *A-C*, *B-C*, *D-E*, *E-F*, *D-F*, *A-E*, *A-F*, *B-E*, *B-F*. The first three of these voltages will of course all be equal and the fourth, fifth and sixth will be equal,

the ratio of these two different sets of voltages being the ratio of transformation. The seventh, eighth, ninth and tenth voltages, that is, *A-E*, *A-F*, *B-E* and *B-F*, are the ones that determine the polarity. Now lay out a voltage phase diagram, remembering that since three-phase transformers are involved the phase position of the voltages as well as their values must be carefully noted. As three-phase transformers are ordinarily designed, they may be connected in delta on both the high-tension and low-tension sides, or delta high-tension and star low-tension, or star high-tension and delta low-tension, or star high-tension and star low-tension, although the last one of these connections is very little used. The



Combination	Voltage Relations			
1	af = be	af < ae	bf > be	af = ae − df
2	af = be	af > ae	bf > be	ae = ae − de
3	af = be	af > ae	bf > be	bf = be + df
4	af = be	af > ae	bf < be	be = be + de
5	af = be	af < ae	bf < be	ae = ae + de
6	af = be	af < ae	bf < be	bf = be − df
7	af = be	af > ae	bf < be	ae = ae − de
8	af < be	af < ae	bf < be	af = ae − df
9	af < be	af < ae	bf < be	be = be + de
10	af = be	af < ae	bf > be	bf = be + df
11	af > be	af > ae	bf > be	af = ae + df
12	af > be	af > ae	bf > be	be = be − de

FIGS. 8, 9, 10, 11 AND 12—DIAGRAMS AND TABLE GIVING MEANS OF DISTINGUISHING BY VOLTAGE MEASUREMENTS BETWEEN THE TWELVE POSSIBLE POLARITY COMBINATIONS

With three-phase transformers delta-connected on both high and low-tension sides.

voltage phase diagram is different for each of these methods of connection, so that they will be considered separately.

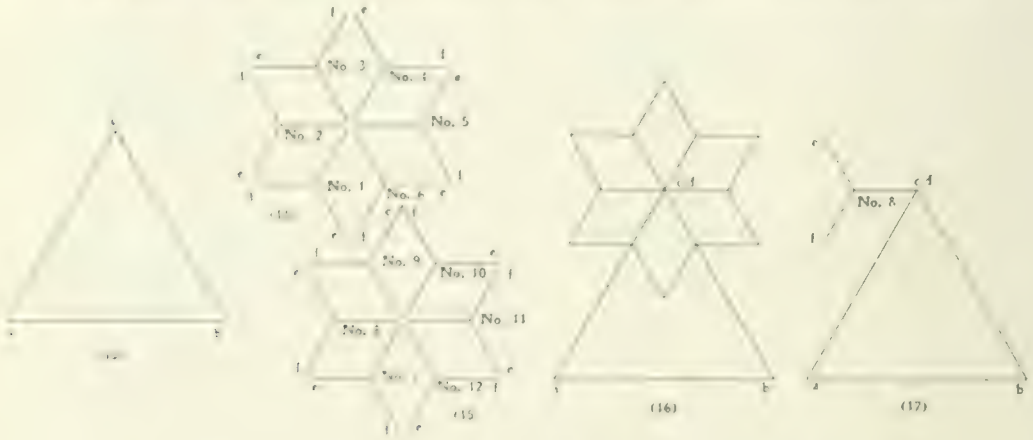
DELTA-DELTA TRANSFORMERS

Considering a transformer connected delta high-tension and delta low-tension, let *a*, *b*, *c*, Fig. 8, be the voltage phase diagram of the high-tension side. Then any one of the six equilateral triangles of either Fig. 9 or Fig. 10 may represent the voltage phase diagram of the low-tension; that is, there are twelve different polarity combinations possible. Now referring to Fig. 11, which shows the high-tension voltages in their phase relation to the low-

tension combinations when C and D (Fig. 7) are connected together, a study of these diagrams will reveal the fact that certain voltage relations hold good for one particular combination that will not hold good for any of the other eleven. The table accompanying Figs. 8 to 12 gives a list of voltage relations for each combination of high and low-tension connections.

With this table and the necessary voltage measurements the polarity diagram of any three-phase transformers connected delta to delta can be laid out in a few minutes. The following example will illustrate the application of the table.

Suppose the measurements are taken and compared with the



Combination	Voltage Relations		
1	af = be	af = ae	bf > be
2	af = be	af > ae	bf > be
3	af = be	af > ae	bf = be
4	af = be	af = ae	bf < be
5	af = be	af < ae	bf < be
6	af = be	af < ae	bf = be
7	af < be	af = ae	bf < be
8	af < be	af < ae	bf < be
9	af < be	af < ae	bf = be
10	af > be	af = ae	bf > be
11	af > be	af > ae	bf > be
12	af > be	af > ae	bf = be

FIGS. 13, 14, 15, 16 AND 17—TWELVE POSSIBLE POLARITY COMBINATIONS

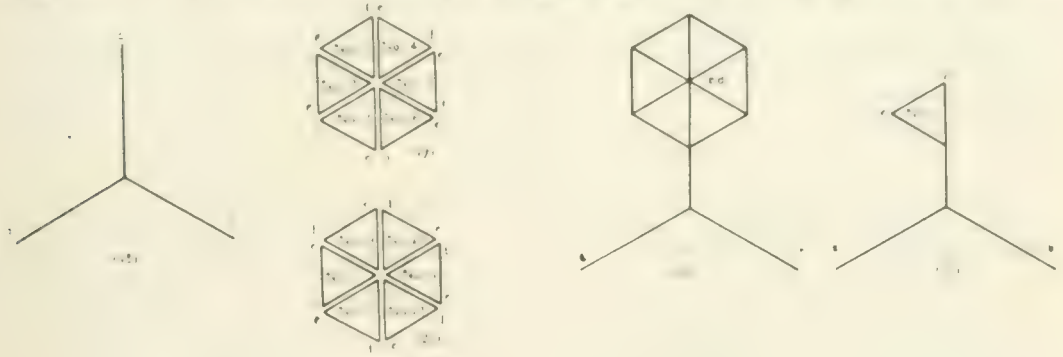
With three-phase transformers delta-connected on high-tension side and star connected on low-tension side.

table, and combination *No.* 5 is found to apply.* Then by referring to Figs. 9 and 10 the position of this combination is quickly located and the polarity diagram, Fig. 12, is easily laid out. This diagram should be laid out to scale. All angles are of course either 60 degrees or 120 degrees. After the diagram is drawn all the voltages should be scaled and they should correspond to the measurements taken on the transformer.

*This is read as follows: af is *equal* to be; af is *less than* ae; bf is *less than* be; ae is *equal* to the sum of ac *plus* de.

DELTA-STAR TRANSFORMERS

With a transformer connected in delta on the high-tension side and in star on the low-tension, the measurements should be taken in the same manner as for the delta to delta connection. Let *a, b, c*, Fig. 13, be the voltage phase diagram of the high-tension side. Then any one of the six groups of either Fig. 14 or 15 may represent the voltage phase diagram of the low-tension; that is, there are twelve possible different polarity combinations. Now refer to Fig. 16, which shows the high-tension voltages in their relation to the low-tension combinations when *C* and *D* (see Fig. 7) are connected together. The table accompanying Figs. 13 to 17 gives a list of



Combination	Voltage Relations		
1	af = be	af = ae	bf > be
2	af = be	af > ae	bf > be
3	af = be	af > ae	bf = be
4	af = be	af = ae	bf < be
5	af = be	af < ae	bf < be
6	af = be	af < ae	bf = be
7	af < be	af = ae	bf < be
8	af < be	af < ae	bf < be
9	af < be	af < ae	bf = be
10	af > be	af = ae	bf > be
11	af > be	af > ae	bf > be
12	af > be	af > ae	bf = be

FIGS. 18, 19, 20, 21 AND 22—TWELVE POSSIBLE POLARITY COMBINATIONS

With three-phase transformers star-connected on high-tension side and delta-connected on low-tension side.

voltage relations, one of which holds good for each of the twelve combinations.

For example, suppose the measurements are compared with the above table and combination *No. 8* is found to apply. Then by reference to Figs. 14 and 15 the position of this combination can be located and the polarity diagram, Fig. 17, laid out.

STAR-DELTA TRANSFORMERS

Consider next a transformer connected star on the high-tension side and delta on the low-tension. Let *a, b, c*, Fig. 18, be the voltage phase diagram of the high-tension side. Then any one of the six groups of either Fig. 19 or 20 may represent the voltage phase dia-

gram of the low-tension, so that twelve different polarity combinations are possible. Fig. 21 shows the high-tension voltages in their relation to the low-tension combinations when *C* and *D* are connected together. The table accompanying Figs. 18 to 22 gives a list of the voltage relations, one of which holds good for each of the twelve combinations. It will be seen by comparing this table with the one given in connection with Figs. 13 to 17 that the two are identical.

For example, suppose the measurements are compared with the above table and combination *No. 7* is found to apply. Then by referring to Figs. 19 and 20 the position of this combination can be located and the polarity diagram, Fig. 22, laid out.

Transformers connected in star on both the high-tension and low-tension sides will not be considered, because this is a connection rarely used.

ODD COMBINATIONS WHICH CAN BE PARALLELED

Comparing the three groups of combinations discussed above, it will be found that a transformer connected in delta on both the high-tension and low-tension sides cannot be made to parallel with one connected either in delta on the high-tension and star on the low-tension or in star on the high-tension and delta on the low-tension side, but that a transformer connected in delta on the high-tension and star on the low-tension can be made to parallel with some combinations of one connected in star on the high-tension and delta on the low-tension side. It will also be found that some combinations of one transformer cannot be made to parallel with some combinations of another transformer using the same type of connections for the two windings. For example, a transformer connected delta to delta may have a combination that will not parallel with another transformer connected delta to delta. By changing the internal connections between the coils, however, it will be possible to bring out the terminals in such a way that parallel operation can be obtained for all combinations.

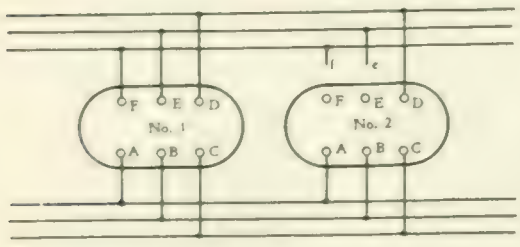
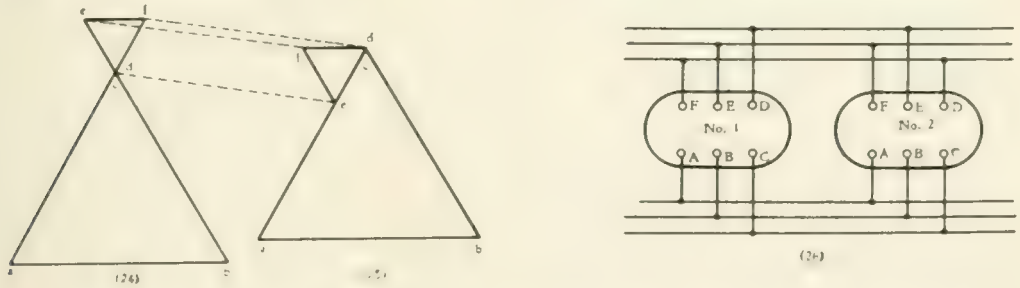


FIG. 23

Referring to Fig. 23, it can soon be determined whether two three-phase transformers have the same polarity by connecting them in parallel on the high-tension and low-tension sides, but leaving terminals *E* and *F* of transformer *No. 2* disconnected. In making these connections similarly numbered terminals should be con-

nected together, that is, *A-A*, *B-B*, etc. If, with this arrangement, there is no voltage between *E* and *e* or between *F* and *f* of transformer *No. 2*, the polarities are the same and the connections can be completed, and the transformers put into service. If, however, there is found to be a difference of voltage between *E* and *e* or *F* and *f*, or both, the polarity of the two transformers is not the same. In this case the polarity of each transformer should be determined separately and the voltage phase diagram laid out to ascertain whether it is possible to arrange the connections in such a manner as to make parallel operation possible.

Suppose the voltage phase diagram of transformer *No. 1* is shown in Fig. 24 and that of *No. 2* in Fig. 25, the lines joining *a* and *b*, *a* and *c*, *b* and *c* of one diagram being exactly parallel to the corresponding lines of the other. Now it will be noted that if triangle *d e f* of Fig. 25 be moved in a straight line *without any rotation* and placed directly over triangle *f d e* of Fig. 24, then *d* of Fig. 25 will exactly coincide with *f* of Fig. 24, *e* of Fig. 25, with *d* of Fig. 24, and *f* of Fig. 25, with *e* of Fig. 24. This means that if the two transformers have their low-tension sides connected in such a manner as to join these corresponding terminals, parallel operation can be secured. Fig. 26 shows the correct connections.



FIGS. 24, 25 AND 26—VECTOR DIAGRAMS AND CONNECTION DIAGRAM
Illustrating paralleling of two three-phase transformers.

In general it may be stated that if the voltage phase diagram of two transformers with the same high-tension and low-tension voltages be laid out in the same manner as shown in Figs. 24 and 25, and if the low-tension part of one diagram can be moved in a straight line *without any rotation* and placed over the low-tension part of the other diagram so that the corners exactly correspond, then parallel operation is possible, but if the corners do not correspond, parallel operation is impossible. As examples, Figs. 27 and 28 show that parallel operation of these two connections is pos-

sible, while Figs. 27 and 29, or 27 and 30, or 29 and 30, etc., show that transformers giving these voltage phase relations will not parallel.

GENERAL CONSIDERATIONS IN PARALLELING TRANSFORMERS

By referring to Figs. 9 and 10, it may be seen, in general, that any low-tension combination indicated by an odd number can be connected so as to parallel with any other odd-numbered combination, but not with any even-numbered combination. The reverse is also true, that any low-tension combination indicated by an even number can be connected so as to parallel with any other even-numbered combination, but not with any odd-numbered combination.

In order to secure perfect parallel operation between two transformers, they should have exactly the same ratio of high-tension to low-tension turns, the same IR drop, and the same impedance drop. For all practical purposes, however, two transformers having the



FIGS. 27, 28, 29 AND 30—ILLUSTRATING THE GENERAL CASE OF PARALLELING ANY TWO THREE-PHASE TRANSFORMERS

same ratio of turns and approximately the same impedance will operate satisfactorily in parallel even if the IR drops are different. Duplicate transformers will of course have the same characteristics and share the load equally. Two transformers of different make or different size will probably have different characteristics, so that when parallel operation is attempted, measurements should be made to determine if each will carry approximately its share of the load.

As a general rule, transformers differing widely in size should not be operated in parallel, particularly if the smaller size has much lower impedance than the larger. Where the impedances differ, the load on the transformer with the smaller impedance will increase and that on the one with the larger impedance will decrease until the two impedances become equal.* For example, if a load of 400 kw be placed on a bank of two transformers, one of 100 kw

*See article on "Parallel Operation of Transformers," by Mr. J. B. Dibbs, in the JOURNAL for May, 1909, page 276.

capacity with three percent impedance and the other of 300 kw capacity with five percent impedance, the load on the 100 kw unit will be increased to approximately 145 kw, while the load on the 300 kw unit will be decreased to approximately 255 kw. In other words, the impedance of a transformer varies directly with the load, so that the load on the 100 kw transformer increases and that on the 300 kw unit decreases until the impedances become equal.

It is not easy for manufacturers to design transformers to operate in parallel when the sizes differ widely, and if tap voltages have to be considered the problem becomes still more difficult; the price may be increased considerably and the performances will probably not be as good as for a standard design.

When two transformers are connected in V on a three-phase circuit, the capacity is $1 \div \sqrt{3} = 58$ percent (approximately) of the capacity of three similar transformers connected in delta. This is due to the fact that for the delta connection the current and voltage of each transformer are in phase with each other, while for the V connection the current and voltage of each transformer are 30 degrees out of phase with each other.

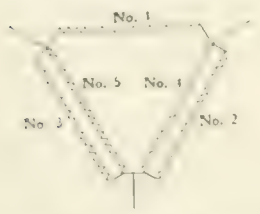


FIG. 31—TWO V-CONNECTED TRANSFORMERS PARALLELED WITH THREE UNITS IN DELTA

When the two transformers connected in V are operated in parallel with three transformers connected in delta, one of the transformers will take more than its share of the load. Such a connection is illustrated in Fig. 31, in which transformers *Nos. 1, 2* and *3* are connected in delta and operated in parallel with *Nos. 4* and *5*, which are connected in V. Without going into the theory it will be found that transformer *No. 1* will be carrying normal load when each of the other four is carrying only 76.15 percent of normal load. It is evident, therefore, that when transformers operate in this manner, *No. 1* must be watched carefully to see that it is not too heavily overloaded.*

There are a large number of other interesting and useful polyphase combinations, but those here given will be found to cover nearly all of the cases commonly encountered.

*For further information on the effect of paralleling various combinations of single-phase units, see article on the "Operation of Delta and V-Connected Transformers" by Mr. E. C. Stone, in the JOURNAL for April, 1910, page 304.

SINGLE-PHASE COMMUTATOR MOTORS

VARIOUS COMMUTATING-POLE ARRANGEMENTS

R. E. HELLMUND and E. W. P. SMITH

IN THE preceding article on this subject the results which may be obtained with shunt connected commutating poles were discussed in detail. In the present article a number of commutating pole arrangements will be dealt with, all of which have been used to good advantage under certain conditions of load and current supply. While with the previously described connections of shunt commutating poles it is possible to obtain satisfactory results under certain conditions of power-factor, short-circuit and reactance voltages in the commutating coils (that is, the coils under commutation), the proportions of these values may change so as to result in comparatively poor commutating conditions with simple shunt connected commutating poles. The various arrangements and connections described below have therefore been developed and used in order to take care of cases involving these more difficult conditions of operation.

In deriving the diagrams for the sparking voltages in the previous paper for the case of shunt connected commutating poles, it was shown that the power-factor had a certain influence upon the best possible commutating conditions. It was shown in one example, for instance,* that in a motor with very good power-factor (under certain assumptions) it is not possible, even under the most favorable conditions, to reduce the resultant sparking voltage below about one-fourth of its value without the use of commutating poles. This condition is even more emphasized in cases where a good power-factor is combined with a comparatively high reactance voltage. Such conditions are found in high speed motors for low frequency, such as 15 cycles, and are represented by the vector diagram, Fig. 1.

In this case the simple shunt commutating poles cannot reduce the sparking voltage to less than about 57 percent of its value without commutating poles. In such cases it is therefore very desirable to induce in the short-circuited coil, in addition to the commutating pole voltage Ei_1, a second voltage Ei_2, which will be seen to be in phase with, but opposite in direction to, the reactance volt-

*See vector diagram, Fig. 11, May, 1912, p. 422.

age *Er* which in turn is in phase with the load current. The remaining part *Es* of the sparking voltage could therefore be compensated for by a field energized by, and in phase with, the load current. (The condition of opposite direction can always be fulfilled by properly connecting the windings). At first sight it would appear simplest to obtain the desired series component of the commutating pole flux by simply adding some series connected turns on the commutating poles carrying the shunt connected coils. Due to the mutual induction of the two coils, however, the desired result cannot be obtained in this manner. In this connection as well as in a number of future considerations it should be kept in mind that in any alternating-current coil the total flux interlinked with the coil must always be proportional to the impressed voltage, and must have a phase relation at right angle to the impressed voltage, assuming that the usually small ohmic drop is neglected. Therefore, the current in the coil will always adjust itself in such a maner as to induce the flux necessitated by the above conditions. If, therefore, a series coil were put around the same commutating pole as the shunt coil, the current in the shunt coil would merely change until it, together with the current of the series coil, would induce a flux in line with these same conditions. This means that, as long as the voltage impressed upon the commutating pole remains unchanged, the commutating pole flux will remain unchanged, and the series commutating pole coil would have no other effect than to change the current in the shunt coil without affecting the flux, except, of course, for a very small amount due to the changes in ohmic drop caused by the change in current.

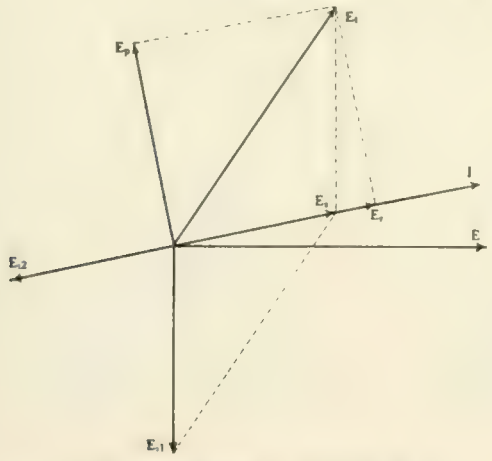


FIG. I—VECTOR DIAGRAM
Showing current and voltage relations in motor having high reactance voltage combined with high power-factor.

Numerous arrangements have been proposed and used to overcome this difficulty, only a few of which will be mentioned here. Fig. 2 shows one of these arrangements. In this case the commutating pole is divided in three parts. A shunt winding is wound around all three of these parts, while a series winding is wound on the middle part only. With this arrangement, the series wind-

ing affects only part of this commutating pole flux and hence changes only the distribution of the total flux going through the shunt connected coil, without affecting its total value. Therefore it is possible to fulfill the above condition; while at the same time, the commutating pole flux in the middle section (i.e., where it is being utilized) can be corrected to have the desired phase, as it has both a series and a shunt component.

A second arrangement serving the same purpose is shown in Fig. 3. Here the commutating pole is slotted in the middle and the main field coils are wound into the slot of the commutating pole. The armature is wound with slightly reduced or fractional pitch so that one side *a* of the coil under commutation is under one-half of one of the commutating poles, while the other side is under the middle of the other commutating pole.* Here again

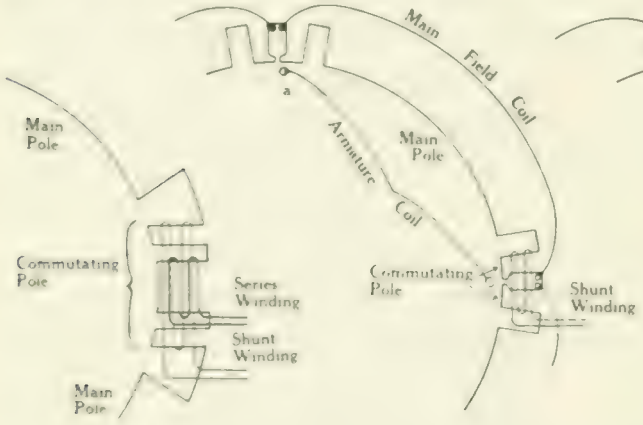


FIG. 2 FIG. 3

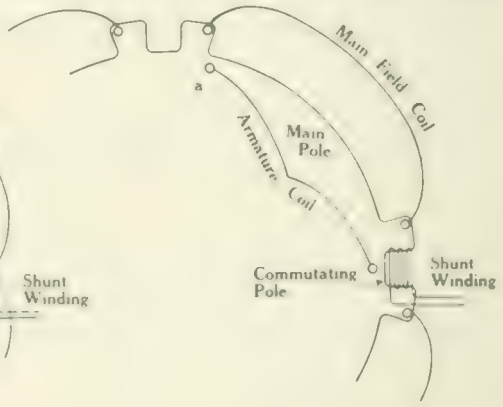


FIG. 4

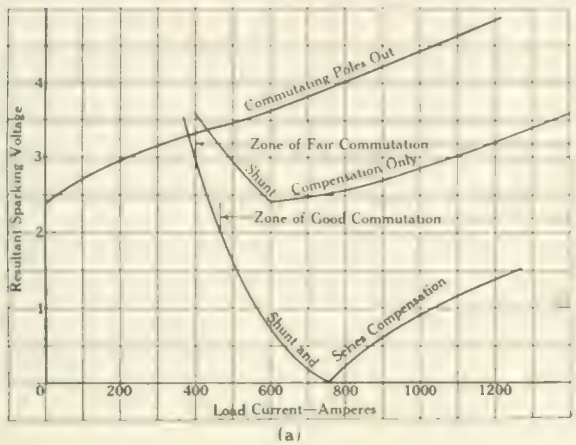
Various commutating pole arrangements.

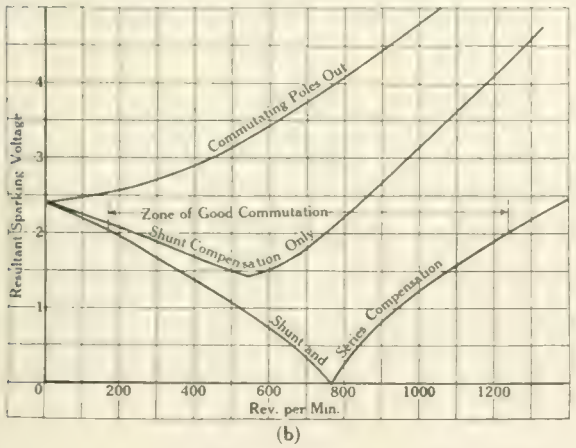
the total flux interlinking with the shunt coils is enabled to conform to the conditions previously pointed out, while the distribution of the flux under the commutating poles can be corrected by the main field coils, which carry the load (series) current. This correction can be so arranged that the voltage induced in one side *a* of the coil under commutation takes care of the component Ei_2 of Fig. 1 while the other half of the same coil takes care of the voltage Ei_1.

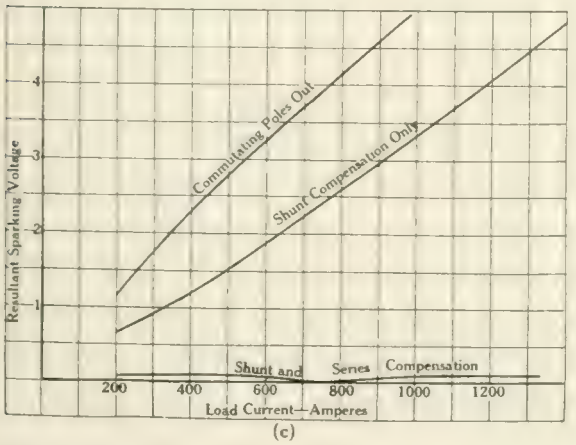
A third arrangement for the same purpose is indicated in Fig. 4. Here the commutating poles have simple shunt connected windings, while the main poles are wound in the usual manner. The pitch of the armature, however, is reduced to such an extent

*See paper by Mr. E. F. W. Alexanderson, Trans. A. I. E. E. for 1908, Part I, p. 1.

that one side of a coil under commutation is always under a commutating pole, while the other side is under one of the main poles. If, in this case, the commutating pole flux is made twice as strong as assumed in the diagrams of the previous article, it will induce the voltage Ei_1 in the one half of the armature coils, while with the proper field arrangement and strength, the main pole will induce the voltage Ei_2 in the other half of the same coil, both voltages being induced by the rotation of the armature.







FIGS. 5 (a), (b) AND (c)—COMMUTATING RESULTS OBTAINED WITH THE ARRANGEMENT OF FIG. 4

(*a*)—Variable speed; variable current.
(*b*)—Variable speed; constant current.
(*c*)—Constant speed; variable current.

As in the case of simple shunt commutating poles, it is possible in all of the above arrangements to get ideal or nearly ideal commutating conditions for only a limited range of loads, for the majority of practical applications. This is because ordinarily the shunt component of the commutating pole flux does not change automatically as desired, although in these cases at least the series component is approximately right for the usual load conditions. In the following a few practically cases are given for the motor arrangement of Fig. 4. This will be sufficient, as it is possible to obtain corresponding results in a similar way with the arrangements of Figs. 2 and 3.

The conditions for the case where the motor is connected to constant voltage and where the load varies are given in Fig. 5a. As is indicated, the upper curve shows the resultant sparking voltage which would exist if no commutating field were provided. The middle curve shows the resultant sparking voltage which could be attained with simple shunt commutating poles, with the assumed conditions; that is, with good power-factor, a comparatively large reactance voltage, and a comparatively small pulsating voltage. The lower curve shows the results which can be obtained with shunt commutating poles and some kind of series compensation as, for instance, with the scheme in Fig. 4. It will be seen that in this case shunt commutating poles alone do not give very good results, and that the additional means of series compensation brings a marked improvement. Good commutation can be obtained for all currents over 470 amperes.

The result for a similar arrangement is given in Fig. 5b, except that here it is assumed that the load torque and therefore the load current is constant, while the speed is varied by varying the motor voltage. It will also be seen here that the results obtained with the above scheme are very good as compared with those obtained with simple shunt commutating poles or no commutating field at all. The voltage of the shunt commutating pole winding has been assumed to be constant.

The results under like assumptions for the case of constant speed and varying load torque which can be obtained by varying the voltage of the motor are given in Fig. 5c. The voltage of the shunt commutating pole is arranged in this case to vary with the motor voltage. It was shown in the previous article* that this arrangement gives the better results. It will be seen from Fig. 5c that it is possible to have the resultant sparking voltage practically zero over the entire range of operation. In other words, the commutation conditions should be fully as good as in a direct-current machine. Fig. 5c shows moreover that the results which could be obtained with simple shunt commutating poles, would not be very satisfactory in this case.

Another scheme for connecting the commutating poles which gives simultaneously the desired shunt and series compensation, has been used to very good advantage by the Oerlikon Company in Switzerland. The commutating pole winding is connected in

*For this connection see Fig. 10 in the May 1912 issue, p. 437.

series with the motor, but has a non-inductive resistance connected in parallel with the commutating winding, as shown in Fig. 6. The vector diagram for this connection is shown in Fig. 7, in which E represents as before the motor voltage, while the motor current I lags a certain angle Φ behind the voltage. The current I divides into Ir and Ii, one of which, Ir, goes through the resistance, while the other, Ii, goes through the commutating pole winding. The two currents must combine of course to a current—I which is equal and opposite to the total current I. It is true moreover, that, as the resistance is practically non-inductive, while the commutating pole circuit is practically purely inductive, the two currents Ir and Ii must combine at practically right angles with each other (that is, under the assumption that the compensating winding fully compensates the armature field, and wherever this is not

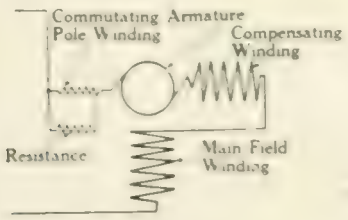


FIG. 6

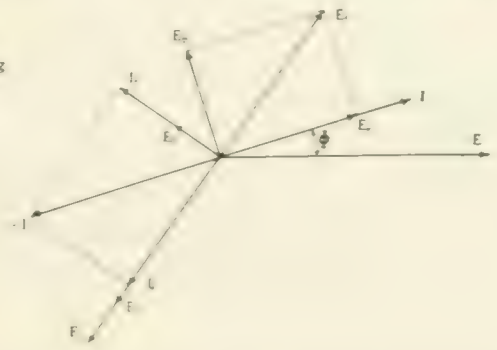
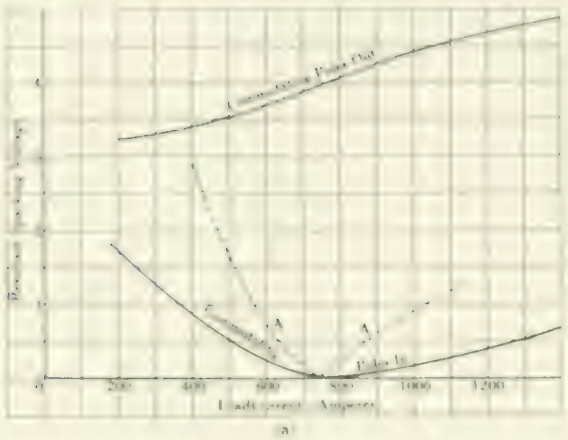


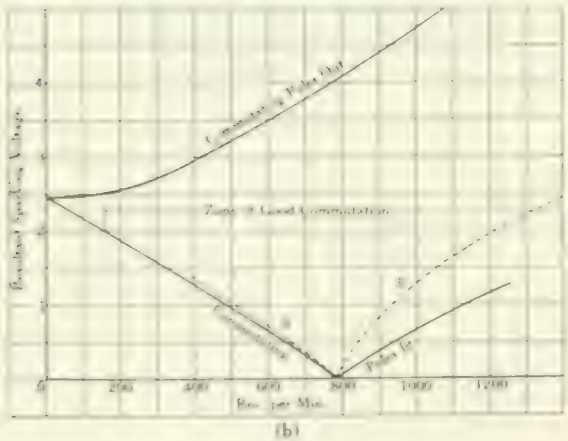
FIG. 7

Non-inductive resistance in parallel with series commutating pole winding. Method used by Oerlikon Company, Switzerland.

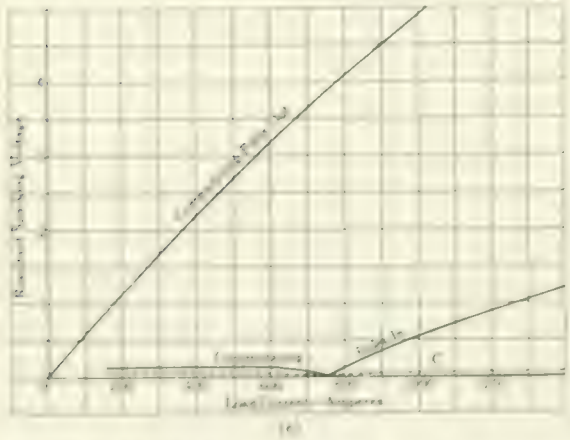
the case, the commutating pole circuit is not necessarily purely inductive). It is moreover evident that as the current Ir goes through a non-inductive circuit, that the voltage Ei causing the current Ir (that is, the voltage at the terminals of the resistance, as well as of the commutating poles) must be in phase with this current Ir. This in turn means that the field flux Fi induced in the commutating pole lags 90 degrees behind this current Ir. It follows from this that the voltage induced by the commutating pole flux in the commutating coil is in phase with this flux Fi and may be represented by the vector Ei. The reactance voltage Er is, as in all previous cases, in phase with the armature current I, while the pulsating voltage Ep lags 90 degrees behind I. The two voltages, Er and Ep combine to the resultant voltage Et, which under the assumptions made is equal and opposite to the voltage Ei induced



(a)



(b)



(c)

FIG. 8 (a), (b) AND (c)—COMMUTATING RESULTS OBTAINED WITH THE ARRANGEMENT OF FIG. 6

(a)—Constant voltage; speed and current variable.

(b)—Variable speed; current constant at 750 amperes.

(c)—Constant speed of 750 r.p.m.; current variable.

by the commutating pole. This, therefore, gives the ideal condition of a sparking voltage equal to zero for this load. Several practical cases of varying load conditions for this method of connection may now be considered.

The case of a motor which is operated at constant voltage while the load varies is represented in Fig. 8a. The resistance is adjusted in such a manner as to get zero sparking voltage at 750 amperes. It will be seen that for this load condition the present connection leads to results which are better than any previously obtained for the same load condition; even better than the results obtained with the connection shown in Fig. 4. (The curve *A*, showing shunt and series compensation, is reproduced from Fig. 5a, for comparison, and shows the superiority of the arrangement of Fig. 6.) Fig. 8b shows the results obtained for the case of constant load torque and varying speed. In this case, also, the present scheme is superior to any other. (Curve *B* in Fig 8b is likewise reproduced from Fig. 5b for comparison). Unfortunately the good results obtained with the present scheme must be

obtained at the expense of efficiency, since the resistance in parallel with the commutating pole will of course consume a certain amount of energy. These losses are in some cases so high that they make the scheme almost prohibitive, while in other cases—for instance in high speed, 15 cycle motors—the magnitude of these losses is not very serious. For instance, in the high speed locomotive motors for the Loetschberg Tunnel it was possible to obtain efficiencies as high as 88 percent, notwithstanding the losses in the resistance. At the same time, the commutation obtained in this case is very satisfactory.

The results obtained with the same connection for constant speed and variable current are shown in Fig. 8c. In this case, the results obtained are not quite as good as those obtained with the scheme shown in Fig. 4. This is due to the irregularity introduced by the saturation curve of the motor, which is automatically taken care of in the scheme of Fig. 4. With a machine of such design that the iron is not saturated, the results possible with the scheme of Fig. 6 are as good as with that of Fig. 4. Nevertheless, for this case of operation the schemes of Figs. 2, 3 and 4 would seem to be preferable, since it is possible to obtain equally good or usually better results without involving as much loss of energy as with the present method.

The previous arrangements were devised, as explained above, for machines with good power-factor and comparatively high reactance voltage, in which case the simple shunt commutating pole did not give very satisfactory results. It was mentioned in the previous article* that with the other extreme, i. e., with very low power-factor and a small reactance voltage, the simple shunt commutating pole does not give very good results either, because in this case a resultant sparking voltage opposite in phase to the reactance voltage would exist. It is possible to obtain better results by connecting the shunt commutating poles in parallel with the armature and the auxiliary winding, instead of connecting them in parallel with the whole motor. This may be explained by referring to Figs. 9 and 10. Fig. 9 shows the connection diagram for this scheme. The conditions of low power-factor, small reactance voltage, and large pulsating voltage are liable to be found in low speed motors for high frequencies such as 50 and 60 cycles.

*See May, 1912, issue, p. 425, second paragraph.

The vector diagram for the connection of Fig. 9 is given in Fig. 10. This diagram, which corresponds in general to the vector diagrams of Figs. 2 to 11 of the previous article, is best derived by starting with the vector *I*a which represents the armature current. The energy voltage of the armature, *E*e, is of course in phase with, and opposite in direction to, the armature current, while the armature inductive voltage *E*l lags 90 degrees behind the current. The reverse values of these voltages, viz.,—*E*e and—*E*l combine to give the voltage *E*a which must be impressed upon the armature. This voltage is at the same time the voltage impressed upon the commutating poles, and since the commutating pole winding may be assumed as a purely inductive circuit, the commutating pole current *I*i lags 90 degrees behind the armature voltage *E*a. By combining the armature current *I*a and the commutating pole current *I*i the

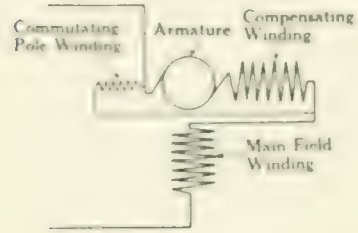


FIG. 9

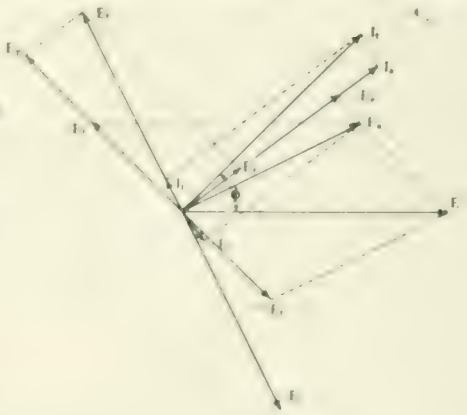


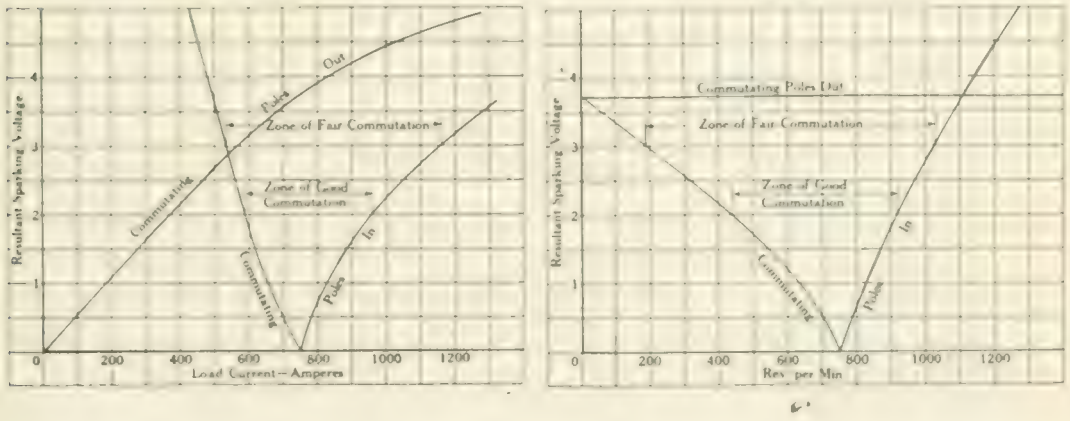
FIG. 10

Commutating pole winding in parallel with armature and compensating winding.

total current going through the main field winding, or *I*t, is obtained. As the inductive voltage of the main field, *E*f, is 90 degrees behind the field current, it can also be determined. (The watt component may be neglected). It is now possible to combine the voltage *E*a impressed upon the armature and the voltage —*E*f, which must be impressed upon the field, and obtain the motor voltage *E*. The diagram is now sufficiently complete to use in considering the sparking conditions. The reactance voltage *E*r, which, by assumption, is to be of small amplitude in the present case, is in phase with the armature current *I*a*. The pulsating voltage *E*p is 90 degrees in phase behind the field current *I*t*. As in any inductive circuit, the commutating pole field flux is 90 degrees behind

*These relations were explained in the previous article in the May, 1912, issue, pp. 421-422

the impressed voltage, and therefore the voltage induced by the commutating pole flux in the coils under commutation is also shifted 90 degrees behind the voltage impressed upon the commutating pole, i. e., the voltage *E*a. This will be evident, as the voltage in the coil under commutation is induced by rotation and therefore is in phase with the flux. The commutating pole flux, however, is shown in Fig. 10 in the oppostie direction as—*E*i, a condition which can be governed by the connection of the commutating pole coil. The voltages *E*p and *E*r combine to give the voltage *E*t, and it will be seen that under the assumptions made *E*t is equal and opposite to the voltage *E*i induced by the commutating pole. Hence, this connection results in the ideal condition of a sparking voltage equal to zero. While it is possible in this manner to obtain good conditions as regards sparking, for one given load case, the change in load has a very unfavorable influence upon this spark-



(a) (b)

FIGS. 11 (a) AND (b)—COMMUTATING RESULTS OBTAINED WITH THE ARRANGEMENT OF FIG. 9

(*a*)—Current variable; speed variable.
(*b*)—Current constant; speed variable.

ing, in fact, more so than in any previous arrangement considered. Fig. 11a represents, for instance, the case where the motor is operated on constant voltage while the load changes. It will be seen that the zone of good commutation is comparatively small. In fact, up to 550 amperes the motor would run much better without commutating poles. The reason that the range of good commutation is so narrow lies in the fact that an increase of current means increased field inductive volts, which in turn means that the armature voltage as well as the commutating pole voltage decreases with increase in current, while the opposite is to be desired.

The case of varying speeds with constant load is represented in Fig. 11b. In this case, also, the zone of good commutation is very small.

An arrangement has been proposed by Latour, of France, which can be applied for both cases previously discussed; that is, one which will give good results for the case of good power-factor and high reactance voltage as well as low power-factor combined with a small reactance voltage. Latour connects the primary of a small transformer across the main field coil, while the secondary of the same transformer is connected in series with a shunt connected commutating pole, as indicated in Fig. 12. Fig. 13 shows the vector diagram, for this connection, for a motor with good power-factor and large reactance voltage. In this figure *I*a represents the armature current, which divides into the field current *I*f and the current *I*t in the primary of the transformer. This latter current has been determined from the commutating pole current under the assumption that no power is transmitted into the motor by this transformer. This condition can be (but is not necessarily) fulfilled by proper arrangement of the compensating winding. The armature voltage *E*a is the resultant of the energy voltage *E*e in phase with the armature current and the inductive armature voltage *E*l shifted through a phase angle of 90 degrees. The total voltage *E* of the motor is the resultant of the armature voltage *E*a and the field voltage *E*f, the latter being approximately at right angles to the field current *I*f. If the small losses and the reactance of the transformer be neglected, the secondary voltage *E*c of the transformer is in phase with the primary voltage, which is the same as the field voltage *E*f. The direction of *E*c is of course determined by the way in which the secondary coil of the transformer is connected into the circuit, and the magnitude of *E*c follows from the ratio of transformation. After *E*c is determined the commutating pole voltage *E*b is also given from the fact that the resultant $-E$ of the secondary transformer voltage *E*c and the commutating pole voltage *E*b must be equal to the motor voltage *E*. The flux *F*i of the commutating pole has a phase position of 90 degrees behind the voltage *E*b impressed upon the commutating pole, and the voltage *E*i induced by this flux in the coils under commutation is in phase with this flux. The reactance voltage *E*r which is comparatively large in this case is in phase with the armature current *I*a,

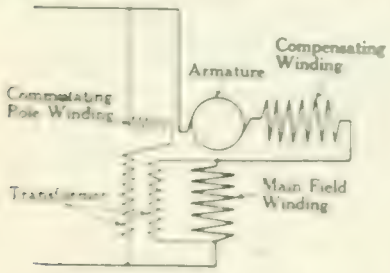


FIG. 12—AUXILIARY TRANSFORMER ARRANGEMENT
Devised by Latour, France

while the field pulsating voltage *E*p lags practically 90 degrees behind the field current *I*f. The voltages *E*p and *E*r combine to give the total voltage *E*t, which, as will be seen, is equal and opposite to the voltage *E*i. Therefore, this again gives a resultant sparking voltage equal to zero.

The vector diagram for the same connection diagram under the assumption that the motor has a low power-factor and a small reactance voltage is shown in Fig. 14. In this case, desirable results are obtained by reversing the transformer voltage *E*c, which means that the vector *E*c has the opposite direction. It also means

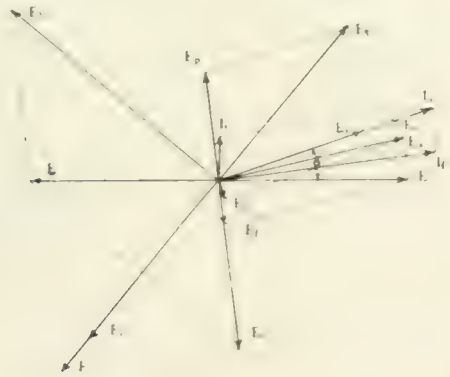


FIG. 13

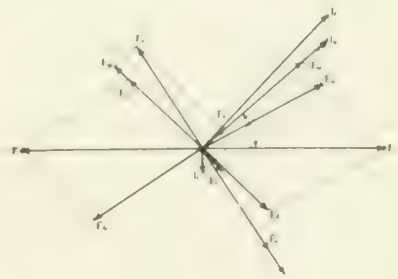


FIG. 14

VECTOR DIAGRAMS SHOWING FAVORABLE RELATIONS OBTAINED WITH THE ARRANGEMENT OF FIG. 12

Fig 13—Motor power-factor high; large reactance voltage.
Fig. 14—Motor power-factor low; small reactance voltage. Satisfactory results obtained by reversing transformer secondary.

that the primary current of the transformer will flow in the opposite direction. Otherwise the derivation of the diagram of Fig. 14 is in principle the same as that of Fig. 13.

In practical operation the arrangement devised by Latour gives results similar to those obtained with some of the schemes previously described. The present scheme, however, has the disadvantage of requiring an extra transformer, which means an additional expense. Therefore some of the other arrangements will probably frequently be used in preference to the one last described, although there may be cases where this scheme can be used to good advantage.

CONNECTIONS FOR SYNCHRONIZING

HAROLD W. BROWN

THE prime requisite in a system of connections for synchronizing alternating-current circuits is that it shall be easy to use and difficult to misuse. This means that the operations must be simple, and the meaning of the indications must be at once apparent.* For example, it should not be necessary for a station operator to stop, while synchronizing a machine, to figure out in which cases the synchroscope rotates in the clockwise direction and in which cases in the counter-clockwise. To this end, certain features are worthy of consideration, as follows:—

1—Where several machines are to be synchronized, the operation of synchronizing should be the same for all machines.

2—When the machines are in synchronism the synchronizing apparatus must indicate the fact clearly; and when they are not in synchronism it is desirable, though not absolutely necessary, to show directly how the machines differ in phase.

3—The operations performed in synchronizing should be as few and simple as possible.

To make the operation of synchronizing the same in all cases, the plugs, receptacles, and lamps should be all of the same types, and similarly arranged for all the machines that are to be synchronized. Usually one panel of the switchboard is devoted to to each machine, and the synchronizing apparatus should have the same arrangement on each panel. When additions to old installations are made, the new panels should be provided with receptacles and lamps to correspond with the old part, or the old part should be changed to conform to the new. As there is usually only one synchroscope in a station, the connections to it should be the same from all the machines.

The synchroscope is required to indicate the phase relation between the machine and the circuit to which it is to be connected. If it is omitted, the operator is dependent on the pulsation of the lamps to give him some idea of the phase relations. The connec-

*The present discussion presupposes that the process of phasing out for synchronizing has already been completed. This is covered in an article on "Phasing Out Polyphase Circuits" in the JOURNAL for May, 1912, p. 437. Information of a more general nature on the subject of synchronizing is given in an article in the series on "Meter and Relay Connections" in the JOURNAL for Sept., 1908, p. 530.

tions to the synchroscope are somewhat more complicated than to the lamps, but in most cases no extra operation is required for using the synchroscope. An arrangement that has much in its favor is to have one synchroscope on the bracket at the end of the switchboard, and to provide a synchronizing lamp on the panel of each generator. Another arrangement is to have one synchroscope and only one lamp, (or two in series) at the synchroscope. The wiring with the latter arrangement is a little simpler than where there is a lamp for each machine, but there is an advantage in having a lamp for each generator on the panel for that generator.

To simplify the operation of synchronizing two circuits, the apparatus should be so arranged, if possible, that only one plug need be inserted, or only one switching device of any other type closed. This is usually possible, but some exceptions will be mentioned.

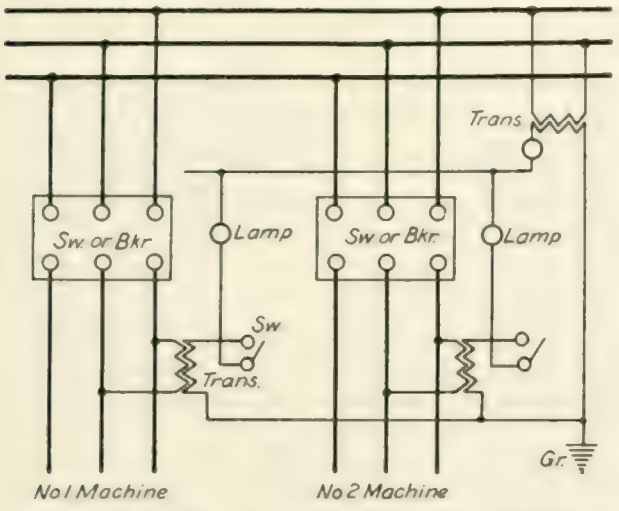


FIG. 1—SIMPLE CONNECTIONS FOR SYNCHRONIZING MACHINE TO BUS BY LAMPS

For synchronizing a machine to the bus by lamps, it is necessary only to insert a plug in a receptacle, equivalent to a single-pole, single-throw switch. This is illustrated by Fig. 1, where one side of the transformer on the bus and one side of each of the machine transformers is connected to a common ground line. Any plugging or switching device capable of closing a single contact could be used for this purpose. If the device consists of a plug and receptacle, only one plug is required for all of the receptacles.

For synchronizing between any two machines by lamps, the outfit and connections are the same as between a machine and the bus, except that the bus transformer and the corresponding lamp are omitted and two plugs are required instead of one.

For synchronizing a machine to one of two buses by lamps, one double-throw or two single-throw switches or equivalent is required. The machine lamp may be inserted between the switch and the machine transformer, so that only one lamp is required for each machine. If 220 volt, instead of 110 volt lamps, are em-

ployed the bus lamp may be omitted, but in this case an interlock should be provided (similar to that in Figs. 3 and 4, or of some other kind), so that it would be impossible to produce a short-circuit by throwing one switch to one bus and another switch to the other bus.

If a synchroscope is used, an extra connection is required, unless the running circuit is left permanently closed. This is illustrated in Fig. 2, where the receptacle is shown in the form of a two-pole, single-throw switch. This is necessary because there are two circuits to be connected to the synchroscope. If any form of receptacle is used instead of a switch, and there is *only one plug* to fit the receptacle, there is no danger of a short-circuit resulting from accidentally making connection to more than one machine

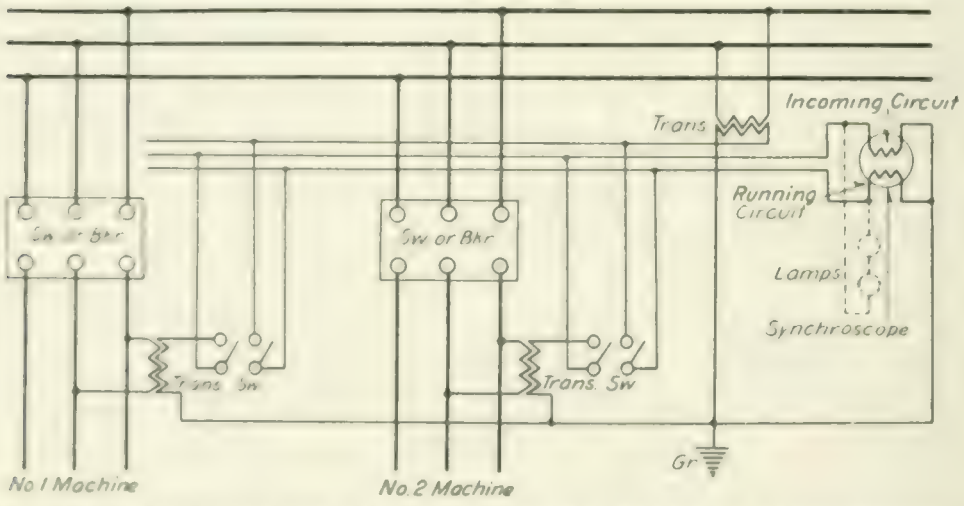
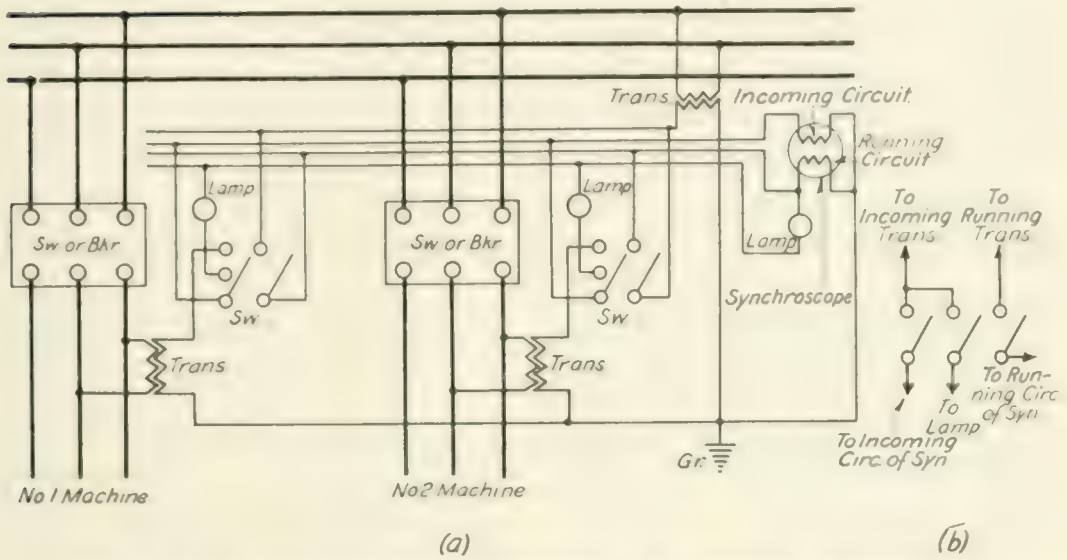


FIG. 2.—CONNECTIONS FOR SYNCHRONIZING BY MEANS OF SYNCHROSCOPE

One lamp or two lamps (as required) may also be used by connecting as indicated by the broken lines. In this case no extra contacts are required for the lamps.

at a time. Similarly if any other form of mechanical interlock is provided, only a two-pole single-throw switch or its equivalent is required. For example, a two-pole push button can be used, if it has a spring which keeps the contacts open except when the operator holds them closed. No extra contacts are required for a lamp or a pair of lamps used with the synchroscope as in Fig. 2; but if a lamp is provided for each incoming machine, an extra terminal is required on the switch or receptacle, as illustrated in Fig. 3. If the switch blade or other connector is long enough to make two contacts, it may be connected as in Fig. 3*a*, where the left hand blade of each switch connects both the lamp and the synchroscope to the transformer on the incoming circuit. Other-

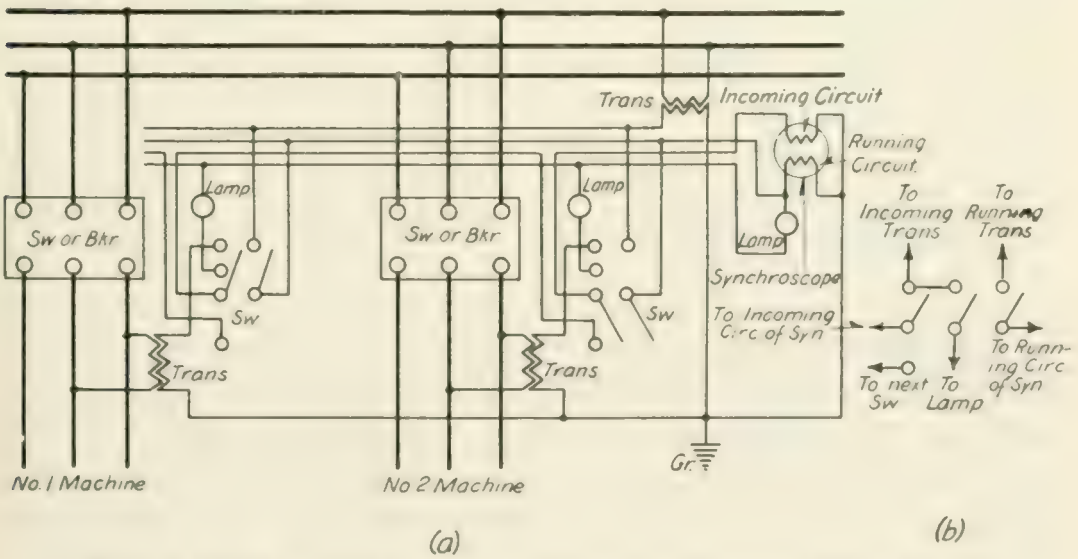


FIGS. 3 (*a*) AND (*b*)—SYNCHRONIZING CONNECTIONS EMPLOYING SYNCHROSCOPE AND LAMPS

These two connections do not provide for interlocking of the synchronizing circuits against accidental short-circuit through closing the two synchronizing switches at once.

In (*a*), special two-pole, single-throw synchronizing switches are indicated, the left hand blade making two contacts.

In (*b*), a corresponding three-pole, single-throw type of switch is indicated.



FIGS. 4 (*a*) AND (*b*)—SYNCHRONIZING CONNECTIONS EMPLOYING SYNCHROSCOPE AND LAMPS

These two connections show methods of interlocking the synchronizing circuits against possible short-circuit through closing of two switches at once.

In (*a*), double-throw switches corresponding to those of Fig. 3 (*a*) are used, while in (*b*), double-throw switches corresponding to those of Fig. 3 (*b*) are indicated.

wise a three-pole device may be employed, as in Fig. 3*b*. As in the case of Fig. 2, the connections of Figs. 3*a* and *b* are safe if there is no possibility of closing two switches at the same time. Otherwise a double-throw switch may be used, as in Figs. 4*a* and *b*. It is then impossible to connect to more than one incoming circuit at a time. In Fig. 4*a* the special two-pole switch corresponds to the switch in Fig. 3*a*, and in Fig. 4*b* the switch corresponds to the one in Fig. 3*b*.

The switches in Figs. 1 to 4 have been shown to illustrate the principles, rather than to show the kinds of plugs and receptacles that are commonly used. The actual receptacles in most common use are illustrated in Fig. 5*a*, *b*, and *c*. For example, the receptacle and plug in Fig. 5*a* are commonly used by the General Electric Company on their switchboards for synchronizing between two machines as indicated. When the plug for the incoming machine is inserted it connects the transformer to the left hand terminal of the receptacle, and thence to the incoming circuit of the synchroscope. When the plug for the running machine is inserted it connects the transformer to the running circuit of the synchroscope. Similarly other uses for the plugs and receptacles in Figs. 5*a* and *b* are at once evident, as outlined in the preceding paragraphs. Again, the plug and receptacle most commonly used by the Westinghouse Electric & Mfg. Company is illustrated in Fig. 5*c*. It consists of two sets of contacts, each set having three contact points, which are connected to each other by inserting the plug. It can be used for any of the connections indicated in Figs. 1 to 4.



FIG. 5 (*a*), (*b*) AND (*c*)—DETAILS OF CONNECTIONS OF COMMON TYPES OF SYNCHRONIZING PLUGS AND RECEPTACLES

In some cases it is desired to make it impossible to close an electrically operated switch without inserting the synchronizing plug in the receptacle for that switch. In such cases an extra pair of contacts is added to the receptacles, and the closing coil of the electrically operated switch is connected in series with these

contacts. In other cases two synchronizing plugs are provided, one with the contact for the incoming circuit only, and the other with the contact for the running circuit only. These plugs, with one contact each, are used for synchronizing between machines in certain cases, as illustrated in some of the diagrams that follow. The plug and receptacle represented in Fig. 5c, or some modification of it, has been used in these diagrams. The diagrams are

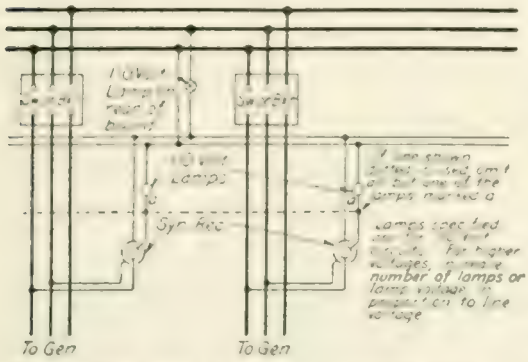


FIG. 6— WITH LAMPS—NO TRANSFORMERS

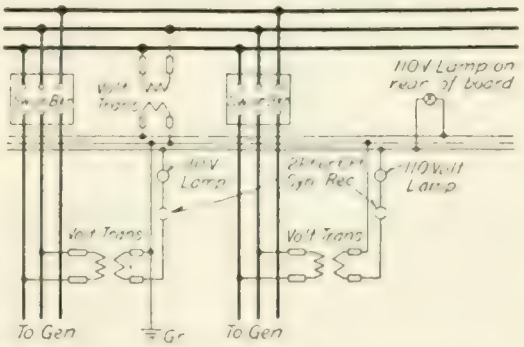


FIG. 7— WITH LAMPS—WITH TRANSFORMERS

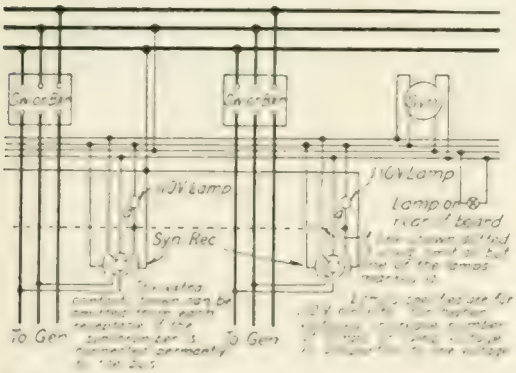


FIG. 8— WITH LAMPS AND SYNCHROSCOPE—NO TRANSFORMER

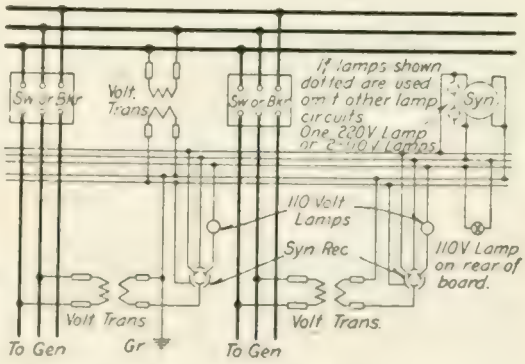


FIG. 9— WITH LAMPS AND SYNCHROSCOPE—WITH TRANSFORMER

FIGS. 6, 7, 8 AND 9—STANDARD CONNECTIONS FOR SYNCHRONIZING TO SINGLE BUS

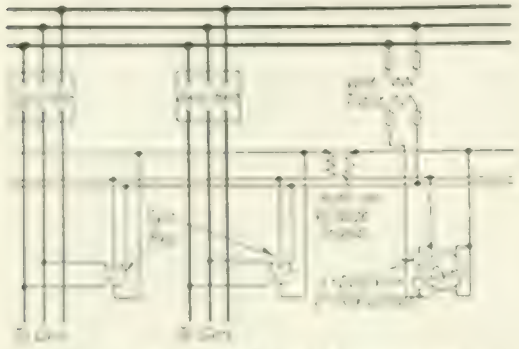
The connections shown dotted in Fig. 9 are used where lamps are mounted with the synchroscope on swinging bracket at end of switchboard.

along the lines indicated in Figs. 1 to 4, and give the complete connections for the more common requirements.

SYNCHRONIZING TO SINGLE BUS

For synchronizing with lamps only, the connections are given in Figs. 6 and 7. If the voltage is so low that transformers are not required Fig. 6 is employed. With this arrangement there is no connection between any bus-bar and the corresponding machine lead except through a lamp. It is desirable to have such an arrangement, because in case of a partial ground the receptacles

might otherwise be required to carry current larger than their capacity. All the subsequent diagrams are similarly arranged, where there are no transformers. In Fig. 7 and all subsequent diagrams in which transformers are shown, one side of each transformer secondary is connected to a common ground. This simplifies the wiring and the switching apparatus, and avoids the possibility of a high voltage existing between windings of the synchroscope due to leakage from the high-tension side of the transformers. Figs. 8 and 9 correspond to Figs. 6 and 7, where a synchroscope is used. The receptacle in Fig. 8 has an extra



With Lamps and Synchroscope—With Only Two Transformers

FIG. 10—SIMPLIFIED LOW VOLTAGE CONNECTIONS FOR SYNCHRONIZING TO SIX-WIRE MAINS

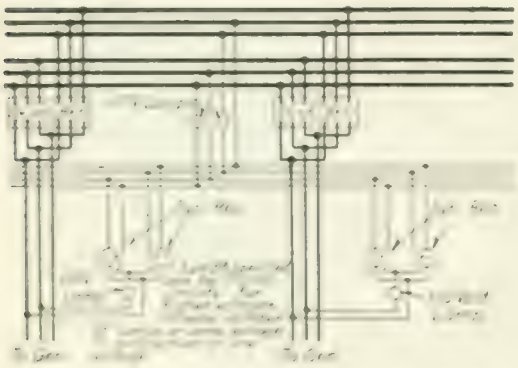


FIG. 11—With Lamps—No Transformers

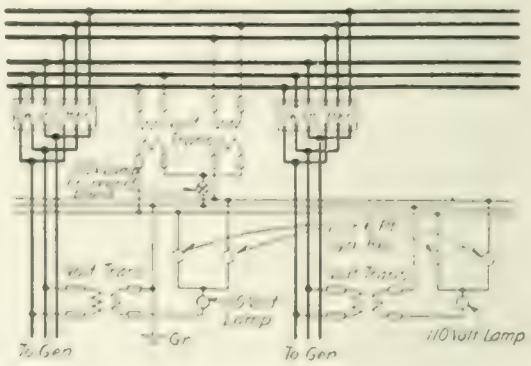


FIG. 12—With Lamps—With Transformers

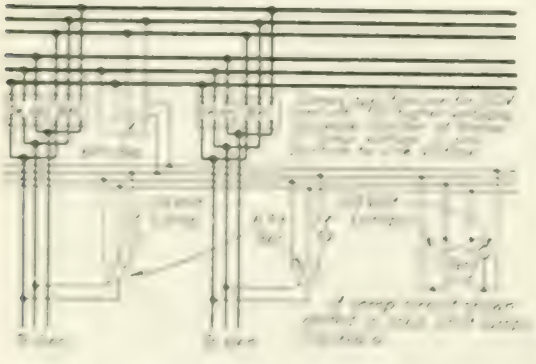


FIG. 13—With Lamps and Synchroscope—No Transformers

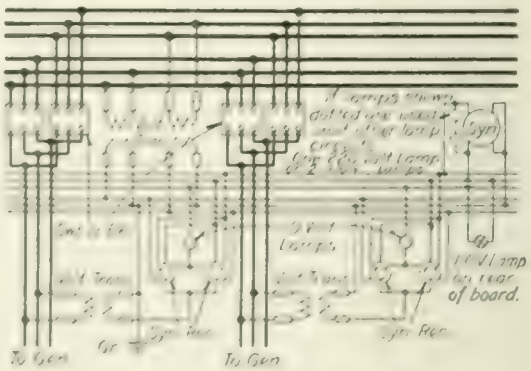


FIG. 14—With Lamps and Synchroscope With Transformers

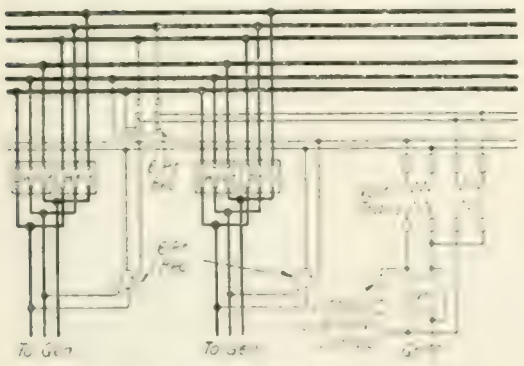
FIGS. 11, 12, 13 AND 14—STANDARD CONNECTIONS FOR SYNCHRONIZING TO DOUBLE BUS SYSTEM

Corresponding to the single line connections of Figs. 6, 7, 8 and 9, respectively.

pair of contacts, so as to avoid connection from any bus-bar to any machine lead except through a lamp. The synchroscope is ordinarily wound for 110 volts. If it is to be used on a somewhat higher voltage—say 440 volts—it is not necessary to provide more than two voltage transformers for any number of machines to be synchronized, if the connections are as illustrated in Fig. 10. One of the transformers may be replaced by an auto-transformer, but in the other transformer the primary circuit must be insulated from the secondary. Otherwise there would be a direct connection between one of the bus-bars and one of the machine leads.

SYNCHRONIZING FOR DOUBLE BUS SYSTEM

The connections of Figs. 11 to 15 correspond to those of Figs. 6 to 10, but are adapted for use where each machine may be connected to either of two buses. In Figs. 13 and 15 two kinds of plugging devices are used—one to connect from the bus-bars to the running circuit of the synchroscope and the other from the machines to the incoming synchroscope circuit. The extra connections are required, as heretofore, for insulation. In the other diagrams for double bus systems only one plug is to be inserted for any synchronizing operation: each machine has two receptacles—one for one bus and one for the other.



With Lamps and Synchroscope
With Only Two Transformers

FIG. 15.—SIMPLIFIED LOW-VOLTAGE CONNECTIONS

For synchronizing to double bus system, corresponding to the single bus connection of Fig. 10.

SYNCHRONIZING BETWEEN ANY NUMBER OF MACHINES

In some cases there are no low-tension bus-bars and in others the buses are sectionalized. It is ordinarily better, then, to synchronize between machines than between a machine and a high-tension bus. If there are more than two machines to be synchronized, or if additions are contemplated, so that eventually there will be more than two machines, the connections should be as in Figs. 16 to 20. The receptacles in Fig. 16 are the same as in Fig. 8. These are the ones with the extra contacts that, as previously mentioned, are sometimes connected in series with closing coils of electrically operated switches. The plugs in Fig. 16 are

the same as in Fig. 8 with one ring removed. The plug shown at the right in Fig. 16 has the ring nearest the handle removed, and the one at the left has the middle ring removed. The inner ring of the diagram of the receptacle represents the ring of the receptacle towards the handle of the plug—that is, when in place, towards the front of the board. The outer ring in the diagram represents the ring farthest from the front of the board. One plug of each kind is required. In Fig. 17 two plugs are required

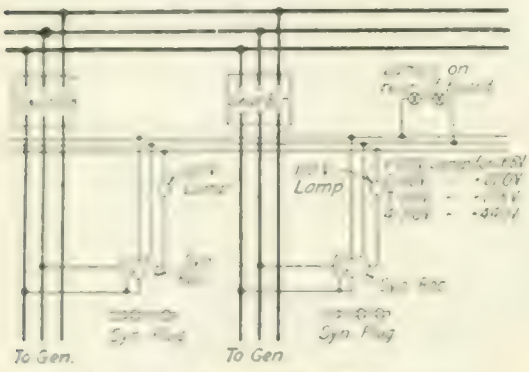


Fig. 16.—With Lamps—No Transformers (Special Plugs)

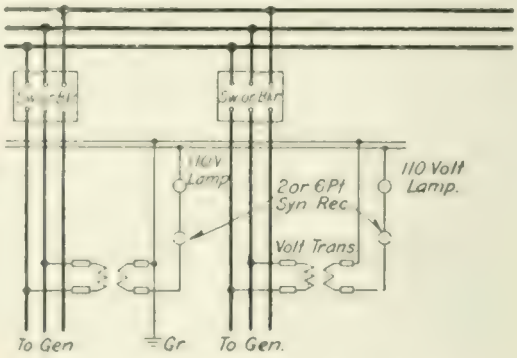


Fig. 17.—With Lamps—With Transformers

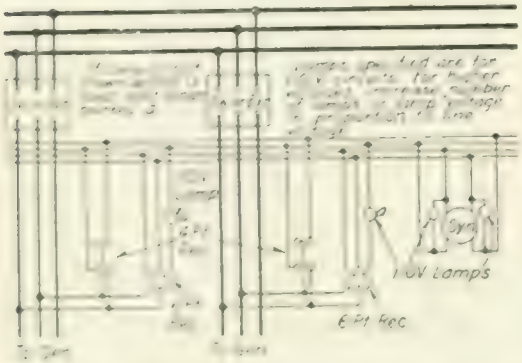


Fig. 18.—With Lamps and Synchroscope—No Transformers

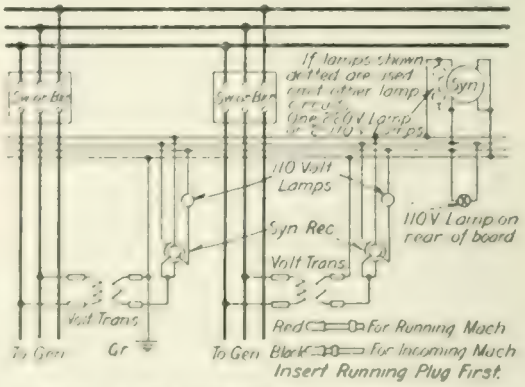


Fig. 19.—With Lamps and Synchroscope—With Transformers (Special Plugs)

Figs. 16, 17, 18 and 19.—Connections for synchronizing between any number of machines.

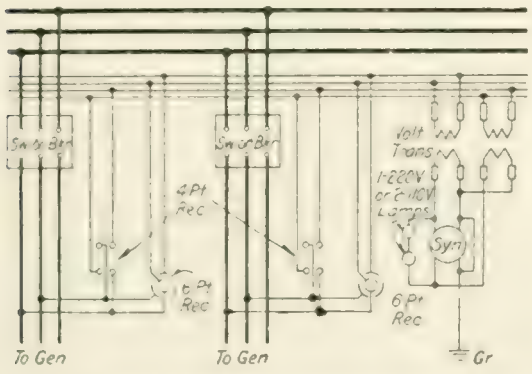
The connections of Fig. 19 may be considered as standard for large installations where the low-tension bus is sectionalized or omitted.

but there is no difference between them. In Fig. 18 an extra four-point receptacle is shown. This is necessary to make the "running" connections without direct connection to the "incoming" circuits. One plug is inserted in the four-point receptacle of the running machine and the other plug is inserted in the six-point receptacle of the incoming machine. Fig. 19 illustrates the use of one standard receptacle for each machine. Two plugs are required, one with only the ring nearer the handle, and the other

with only the ring farther from the handle. The plugs and receptacles in Fig. 20 are the same as in Fig. 18.

SYNCHRONIZING BETWEEN ONLY TWO MACHINES

If there are only two machines to be synchronized, the operation is simpler than if there are more machines, because only one plug is to be inserted. The connections are as shown in Figs. 21 to 25. It will be seen by comparison that the connections and equipment shown in these diagrams are so different from those in Figs. 16 to 20 that if additional machines are later to be installed the synchronizing arrangements should conform to the future requirements. With the connections of Figs. 21 and 22, it makes no difference whether the plug is inserted in the left or right hand receptacle. In Figs. 23 and 24 the right hand receptacle is omitted, and the connections are correspondingly simplified. There is little advantage in having the two receptacles except to make the panels for two machines the same. In Fig. 25 it is desirable to have a receptacle for each machine, because if the plug is inserted in the receptacle for the running machine the synchroscope will rotate in the wrong direction.



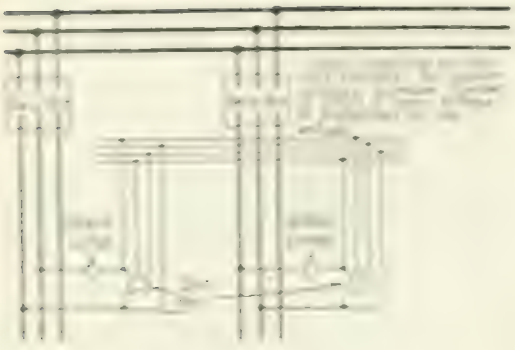
WITH LAMPS AND SYNCHROSCOPES —WITH ONLY TWO TRANSFORMERS

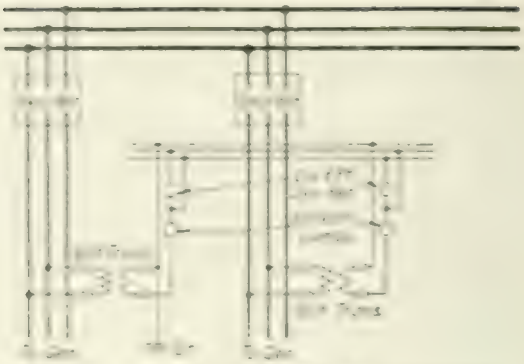
FIG. 20—CONNECTIONS FOR SYNCHRONIZING BETWEEN ANY NUMBER OF MACHINES WITH VOLTAGES UP TO 440 VOLTS

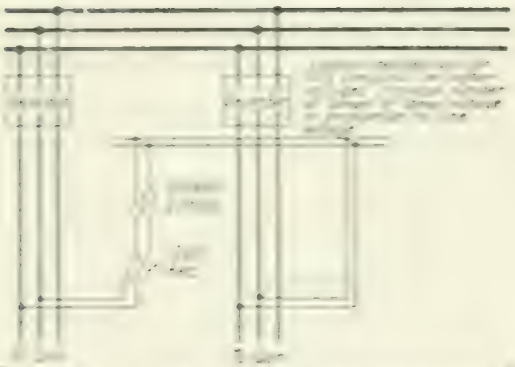
The connections are simplified by using only two transformers.

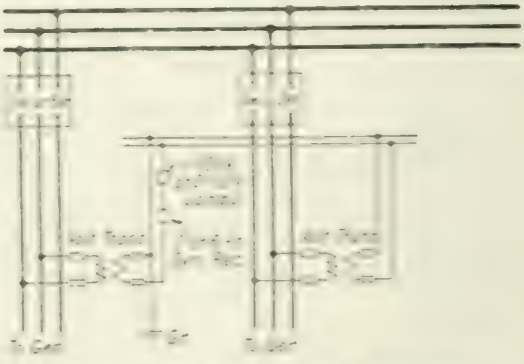
GENERAL

The foregoing diagrams, in several instances, show some circuits dotted, or indicate other possible variations that are explained in the individual diagrams. The purpose of these variations is to cover as nearly as possible all the various requirements in synchronizing, with comparatively few diagrams. The voltages for which the diagrams are adapted depend on the apparatus indicated in the diagrams. If the synchronizing apparatus consists only of plugs, receptacles and lamps, the voltage is limited by the plugs and receptacles, and may be anything up to, say, 440 volts. If a









FIGS. 21, 22, 23 AND 24—CONNECTIONS FOR SYNCHRONIZING BETWEEN DIRECT TWO GENERATORS

Applicable where no protection is required for additional machines.

synchroscope is used without transformers the voltage is limited by the synchroscope, which is usually wound for approximately 110 volts. If suitable voltage transformers are used on all circuits there is no limit to the voltage. If two transformers are used with the synchroscope, but the receptacles are connected directly to the buses and leads, the voltage is of course limited by the receptacles.



FIG. 25—CONNECTIONS FOR SYNCHRONIZING BETWEEN GOLE TWO GENERATORS

Only a few types of receptacles, and only one type of synchroscope, are indicated in the diagrams, but there should be no difficulty in adapting the diagrams to other forms of apparatus if desired.

MOTOR-OPERATED ROLL LATHES

E. M. WISE

IN KEEPING pace with the development of rolling mills for ever-increasing tonnage, and the consequent selection of more durable material for rolls, the lathes for finishing the rolls have also undergone a process of evolution. The early belt drive, with cone pulleys giving only four or five speed changes, did not furnish enough flexibility of speed and was superseded by constant speed motor drive with either change gears or variable speed transmission consisting of adjustable cones engaging a belt. Both of these methods were found unsatisfactory, and the present accepted drive is by adjustable speed motors giving the following distinct advantages:—

1—Maintenance cost is less than by variable speed mechanical transmission.

2—Less time is required for speed changes than by any of the methods formerly used. When a hard spot is reached, such as frequently occurs when turning on the necks of a chilled roll, or surface of a high carbon cast steel roll, the speed can instantly be reduced, and after the spot is passed can again be increased to normal without loss of time.* If desired a controller can be arranged so as to make these changes automatically, by slowing down the motor when the current exceeds a predetermined value.

3—The ratio of gearing between the motor and lathe spindle is always constant.

4—Motor drive in general has the advantage of giving reverse speed by which the lathes can be backed to relieve the tension on the driving spindle, permitting easy removal of the roll from the lathe.

The selection of a motor for a roll lathe depends on the variations of cutting speeds required which, in turn, depend on the material in the rolls to be turned, as follows:—

1—Chilled iron rolls, such as are used in sheet and tin plate mills, are turned at from 46 to 54 inches per minute.

2—Cast steel rolls used in blooming and roughing mills are turned at from 12 to 16 feet per minute.

3—Cast iron rolls, used on structural and shape mills, are turned at from 16 to 20 feet per minute.

In addition to the above variations in cutting speeds for dif-

*Sometimes the necks have spots that are hard, or a plain sand roll may show the same condition in the body. The increased speed may also be secured when passing the "gap" in gap rolls, which are used in shovel mill work.

ferent materials, the fact that the neck bearings of the rolls in general use are from 0.6 to 0.8 times the diameter of the body of the rolls makes an additional requirement.

It is evident that a lathe used for turning cast steel rolls only could handle quite a range of work with a motor having a speed adjustment of 3 to 1, while a lathe used for turning both cast iron and chilled iron rolls would not have a very extensive range even with a motor having a speed adjustment of 4 to 1. The general practice, however, is to maintain lathes for each kind of rolls. The 3 to 1 and 4 to 1 motors usually have a sufficiently wide range to cover their respective classes of work.

If a lathe is required to handle a very great range of work, such as in a manufacturing plant, it is equipped with a double gear reduction (a high and a low speed) controlled by a jaw clutch. With this arrangement the total range of speed adjustment equals

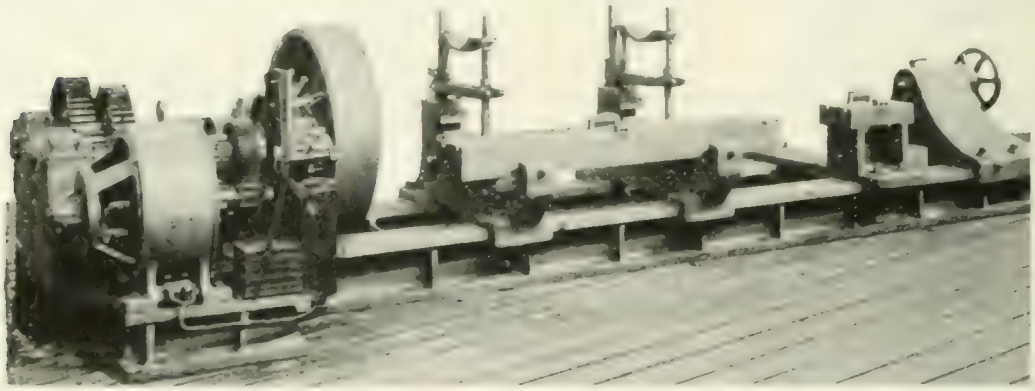


FIG. 1—ROLL LATHE, EQUIPPED WITH CHANGE GEAR AND 3 TO 1 VARIABLE SPEED MOTOR, GIVING A TOTAL SPEED RANGE OF 9 TO 1

the square of the motor adjustment; that is, a lathe equipped with a 3 to 1 motor and a double gear reduction has a 9 to 1 total range of adjustment. For example, assume a lathe equipped with a motor running at 400 to 1 200 r.p.m. and having a maximum gear ratio of 800 to 1. On low gear, such a lathe would run from ½ to 1½ r.p.m by held adjustment; by stopping the motor and throwing in the high gear with a gear ratio of 270 to 1, the lathe would run from 1½ to 4½ r.p.m., making the total variation 9 to 1, and double the changes of speed provided for by contacts on the controller.

It is advisable to have the motor run at as high a speed as is consistent with good commutation and smooth running of the motor pinions; by using rawhide, a maximum pitch line speed of 2 500 feet per minute can be employed with good results. High

motor speed permits greater gear reduction, giving steadier turning movement and tending to eliminate the chattering of the tool when cutting.

The most common sizes of roll lathes, designated by the maximum diameter that will swing clear of the tool rests, are 26, 32, 36, 42, 50 and 60 inches, requiring motors varying from 7 to 30 horse-power. The 60-inch lathe will turn the largest roll used.

A roll lathe differs widely from the ordinary engine lathe, having neither carriage, ways nor cross-slide. Broad flat cutting tools, from 3 to 6 inches, for cast iron and cast steel, are securely clamped in position on the tool bed, directly in front of the roll to be turned. The tool is backed by a screw and is forced into the roll by a long handled wrench. As the lathe is not equipped with a longitudinal feed, the material is cut from the rolls in bands the

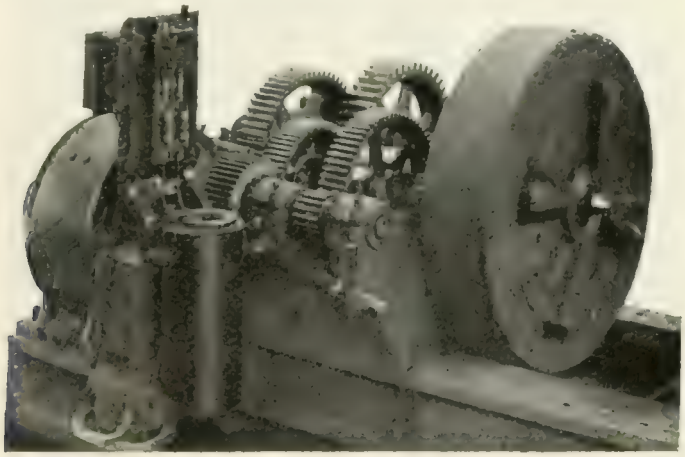


FIG. 2—CONTROL MECHANISM AND GEARING OF MOTOR OPERATED ROLL LATHE

width of the cutting tool, which must be reset for every band; for example, in turning a roll with a body eight feet long, using a tool six inches wide, the tool would have to be reset not less than sixteen times to take off a cut the full length of the roll. Chilled rolls are turned in a similar manner, except that the width of the tool varies from 6 to 12 inches, and the cut is very fine.

In a test made on a 26 inch roll lathe with one 3-inch tool while turning a 10-inch cast steel roll containing 0.6 percent carbon, the motor took 25 amperes on a 230 volt circuit, or approximately 7.7 horse-power input. On the same lathe with a 6-inch tool with the same sized roll of chilled iron the motor took 10 amperes, or approximately 3.1 horse-power input.

In a test made on a 50-inch roll lathe with two 5-inch tools,

equipped with a 14 horse-power, 400 to 1 200 r.p.m., adjustable speed, commutating pole motor, while turning a 26-inch diameter cast steel roll of 0.7 percent carbon, 180 amperes on a 230-volt circuit, or approximately 55 horse-power input, was required. This load was excessive, being practically 300 percent above capacity and the lathe had to be shut down frequently in order to let the motor cool off, although the commutation was entirely satisfactory.

A test made on a 60-inch roll lathe with two 5-inch tools, which was equipped with a 25 horse-power, 560 to 1 120 r.p.m., adjustable speed, shunt wound motor, while turning a 28-inch roll

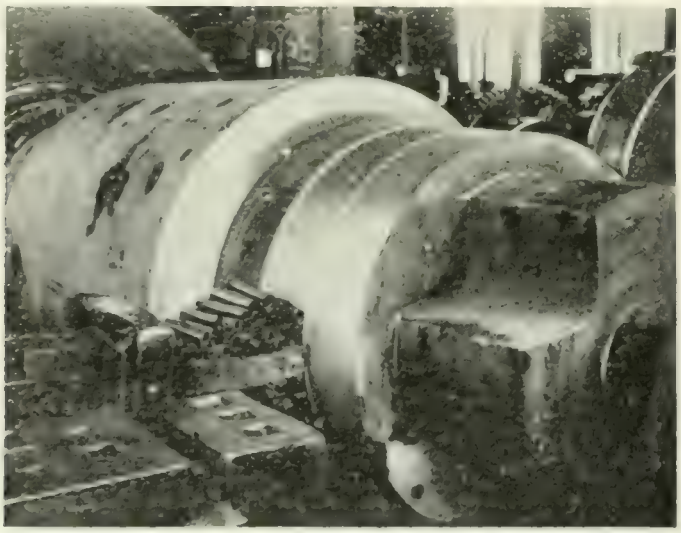


FIG. 3—LATHE TOOL AND TOOL HOLDER USED ON ROLL LATHES

of cast steel, cutting at sixteen feet per minute, indicated that 210 amperes on a 230-volt circuit, or approximately 63 horse-power input, was required. The material removed from the roll was 415 pounds in twenty minutes. This motor also developed considerable heat.

The work on a roll lathe is slightly intermittent; for instance, there is an interval of from three to ten minutes every hour for setting and grinding tools. The maintenance cost of brushes and armature of the motors used in the above tests was very high as a result of the fact that, in the majority of cases, the motor was not large enough for the work required.

THE CARE OF MACHINERY

G. D. OTTAWAY

IN the equipment and operation of an industrial or manufacturing works of any magnitude comprising, as it frequently does, some thousands of machine tools, there is apt to be a general tendency to get into a slipshod way of treating machinery. There is no reason for such an attitude, as each tool or piece of machinery usually has someone whose duty it is to give it his daily attention on production. Anyone, who has been closely associated with the purchase, installation, upkeep and final disposal of shop equipment for a number of years, knows that in general there is a strong tendency toward negligence on the part of shop men, and accordingly a few suggestions will be offered, particularly to those who are directly or indirectly responsible for the upkeep of equipment, which, if applied, will both tend to decrease the initial outlay, and will also increase the efficiency and market value of the apparatus.

In purchasing new machinery do not order useless accessories. Machine tools are like an automobile in one respect, viz., that there are a large number of accessories which the supplier is only too willing to include, if not told specifically that they are not required. It behooves everyone connected with the purchase of new machinery to familiarize himself, through the medium of catalogs, for instance, with equipment that may or may not be included with any specific machine, as such accessories will often raise the cost to fifty percent more than that of the bare tool. One has only to walk around any large manufactory to find hundreds of dollars' worth of equipment so ordered, a large proportion of which has hardly ever been used. After it is once purchased the manufacturer will not allow very much, if anything, for the return of such equipment, so that it is practically a dead loss except when finally sold to a second hand dealer.

Do not order high grade apparatus when low grade will do. It is folly, for instance, to order a high grade milling machine for milling a substance like soapstone, the dust from which is highly detrimental to the wearing parts of the machine. Another item, too, that is not given enough attention, is the question of refinements. It is a waste of money to order, for instance, a milling machine with all power feeds, when the only one that will ever be used is the longitudinal feed. It is poor economy to order a fully equipped engine lathe with all change gears, when it is only intended to do plain turning, for which a stud lathe would suffice.

In the care and upkeep of machine tools, one of the most neglected features is oiling. It is no infrequent thing to come across a machine in which the oil holes are completely choked with dirt and grease. Sometimes, too, the manufacturer has neglected to drill the oil hole entirely through the shell to the bearing; but this can quickly be detected if a systematic system of oiling is followed. It is good economy to be a little too liberal with oil, especially on new apparatus. When first starting, a light oil should be run through the bearings, to wash out the grit, etc., which has entered in transit from the factory. Follow this with machine oil and run light for several hours before putting a job on the machine.

In most factories it is necessary to devote 30 minutes or more once a week to cleaning. In a large percentage of cases this means simply "a lick and a promise." The writer has seen machines being sold second hand which had one-eighth inch of dirt and grease on some parts, showing that there had never been a good and thorough cleaning. Apart from the effect on accuracy during service, a condition like this considerably depresses the second hand value. In operating machines, one of the most useful requisites is "horse sense." It is a common occurrence to come across drill presses on which the table is fairly honey-combed with holes where a careless operator has allowed his drill to go through the work into the table. A packing block or a pair of parallels under the work or jig would eliminate the chance of such damage. Another common practice is to tighten binder handles with a hammer, with the result that they soon break and have to be replaced. There is certainly no necessity for this as the designer of the tool has allowed for average power to be applied, and has undoubtedly made the handle with sufficient leverage to transmit the necessary tension or compression. The same remarks apply to the practice of increasing the leverage by slipping a pipe over the end of a wrench to tighten nuts, which practice almost invariably results in breakage. The beds of lathes are also apt to be subjected to a large amount of abuse, as they are frequently used as pounding blocks, for cleaning out files, and a number of other purposes, all of which leave nicks and dents along the ways, and render them unfit for accurate service. In one case a drilling machine had several adjustable heads held in the desired location by a clamp, and if it was desired to move one of the heads, all that was necessary was to loosen the clamp, slide the head to the desired position and again tighten the clamp. The operators would only partially loosen the

clamp and would pound the head along the cross rail with a hammer to the desired location, with the result that the heads were continually being broken. It was not until one operator, brighter than his fellows, suggested the use of a screw and nut to move the head to the desired location that the trouble was eliminated.

It should be borne in mind also that ultimately apparatus has to be disposed of, preferably by sale, and that all the care bestowed upon it enhances the second hand value. Due to the difference in the class of help, too, a production machine is frequently more neglected than one in tool room work, and this has the effect of considerably shortening the life of the machine. In these days of intensified production, this condition is repeatedly made the excuse for tools having to be discarded after a very short life; but this is not always the real reason, for we have seen machines from tool rooms disposed of which were still in such good condition after 20 years of service that they brought considerably more than scrap price, and simply because they had been given intelligent attention. The old time machinist and apprentice, alike, took a pride in keeping his machine shining and in good accurate condition, and vied with his fellows in this; but this feeling seems no longer to exist, and the cause is not apparent. The equipment pertaining to the machine should preferably be kept adjacent to it, in a cupboard if possible, and not left around in imminent danger of being broken, or carted to the scrap pile in one of the periodical cleaning up days, in which most shops indulge. Even though such equipment may be worn considerably, it is well worth while when the time comes that it is desired to dispose of the apparatus second hand. The first question the prospective buyer is likely to ask is, "What equipment have you pertaining to this apparatus"? It is needless to say that machinery should not be allowed to get inaccurate or worn without being sent to the repair department for overhauling.

The foregoing remarks also apply, in general, to upkeep and use of jigs and fixtures. It is common practice for some operators to return jigs to the tool room with hardly any cleaning, even after they have been used with water, with the result that rust and inaccuracy are soon very much in evidence. It takes but a few minutes to clean these. Why is it neglected? The only sure method of remedying such evils is by a heartier coöperation between workmen and foremen and an earnest, united effort towards the conservation of efficiency of machinery.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

753—Re-arrangement of Generator Equipment—We have a 75 kw, 125 volt direct-current generator, and a 100 kw, 600 volt three-phase 25 cycle generator direct-coupled to a 200 hp gas engine, one machine being located on each side of the engine. Will it be practical to re-arrange the apparatus so that both generators will be located on one side of the engine and have a friction clutch between them and the engine? If so, we could then start up with the gas engine and put the alternating-current machine on the line as a synchronous motor and let it drive the direct-current generator; then, after throwing out the clutch, we could shut the engine down. We have plenty of alternating-current power, but are short on direct-current power. Will the 100 kw alternating-current generator run satisfactorily as a synchronous motor on 600 volt, three-phase, 25 cycle power from generators driven by gas engines, or will it be necessary to equip the revolving part of the 100 kw generator with copper bars and short-circuiting rings to cut down the hunting effect?

W. S. C.

If the mechanical strength of the shaft and the arrangement of bearings are suitable, there should be no difficulty in effecting the change in arrangement of apparatus suggested. For example, if the set were still to be used as at present for the generation of both alternating and direct-current power up to the capacity of the engine, there would of course be increased torsional stress in the shaft with the apparatus located all on one side of the engine; this would be minimized if there were a bearing on each side of the engine, as is probably the case. As regards the electrical features of the proposed method of operation, it may be stated that, in general, the use of dampers is advisable in the case of either gas engine driven alternators or synchronous motors. If, however, the present alternator operates satisfactorily with the other alternators of the system without the use of dampers, it probably would also give good service as a synchronous motor. Under the new arrangement it would be well to try the alternator without dampers; if found necessary they could later be added. The operation of gas engines in connection with generators of capacities such as the total in the present case is such that satisfactory results ordinarily are obtained as regards regulation, although there would no doubt be noticeable voltage variations due to the cyclical variations of crank effort of the engine. This effect is ordinarily kept within satisfactory limits by the use of a suitable fly-wheel. The design of alternators is ordinarily such that their inherent synchronizing power is sufficient to maintain them in step under usual operating conditions, even with gas engine drive. Dampers, applicable in case of hunting, or to prevent it, serve to increase the synchronizing power.

N.S. and E.D.D.

754—Transmission Line Capacity and Self-Induction—*a*—How does line capacity affect the phase relation between the e.m.f and current? What is the exact meaning of line capacity? *b*—What device can be connected to a line to partly neutralize its self-induction? *c*—A coil of wire wound on an iron ring has a resistance of five ohms and an

inductance of 0.5 henry; the impressed e.m.f. is 100 volts and the frequency 30 cycles per second. What current will flow through the coil? Please show the method of figuring. *d*—A sixty cycle alternator is connected to a circuit having an inductance of 0.08 henry and a resistance of 15 ohms. What voltage must be supplied by the alternator to force a current of 15 amperes through the circuit?

G.W.S.

a—The effect of line capacity is to cause the line to draw a leading current from the generating system—that is a charging current to "fill up the line" with electricity during each alternation. If the circuit is of low voltage and of moderate length the charging current, which is 90 degrees in advance of the voltage, represented vectorially, is very small and would have no appreciable effect on the total current. If, on the other hand, the voltage is high and the line long the charging current may, in some cases, become comparable to the load current and so increase the total current. *b*—Theoretically a condenser or a synchronous motor overexcited will take a leading current and so neutralize some of the *effect* of line self-inductance. Line self-induction itself cannot be neutralized. A line is electrically elastic as though the wire were replaced by an elastic rubber tube and the electricity by a fluid. When the pressure of this fluid is increasing there will be a flow of current into the tube to expand and fill it. When the pressure reaches a maximum the tube will be expanded and full and consequently there will be no flow of current. As the pressure reduces there will be a reverse flux as the tube contracts. This flow of fluid is entirely independent of the flow in the electric circuit required to do the work at the receiving end, such as running the motor. *c*—The coil of wire referred to, having five ohms resistance and 0.5 henry inductance would, with 100 volts, 30 cycles, carry current as follows:—The impedance i. e., combined inductance and resistance is determined thus, — Imp. =

$$\sqrt{R^2 + 4\pi^2 N^2 L^2},$$

If $R = 5$ $N = 30$ $L = 0.5$, then, Imp. $= \sqrt{25 + 8883} = 94.4$.

$$\text{Amperes} = \frac{\text{Volts,}}{\text{Impedance}} \quad \frac{100}{94.4}$$

$= 1.06$. d—This case is similar to the above. Volts ÷ Impedance = Amperes; then, Imp. =

$$\sqrt{R^2 + 4\pi^2 N^2 L^2},$$

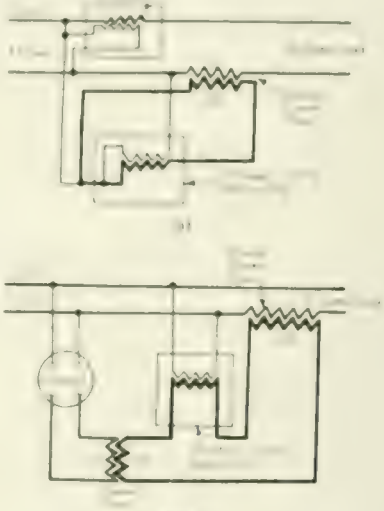
as before. $R = 15$. $Amp. = 15$. $N = 60$, $L = 0.08$. Imp. $= \sqrt{225 + 910} = 33.6$, Volts $= 33.6 \times 15 = 504$. The above voltage is necessary to force 15 amperes through the circuit described. R.P.J.

755—Apparatus for Recording Telephone Conversations—The following apparatus is proposed as a means of recording conversations over the telephone. Considering a telephone instrument, splice an additional receiver *B* on the receiving line; place *B* over the mouth piece of a dictaphone, and what is received over the line will be recorded. Is this commercial? One difficulty is that the record cannot be filed away and reproductions are available only as long as the wax cylinders are kept. The natural question is then, "Cannot the conversation be transcribed on a typewriter?" Yes, but this transcription is worthless as evidence. I have been trying to find a way to make this record on paper or on files which would cost less than five cents apiece. It may be that there is a way to make an impression in permanent material from a flat wax record. This process could be handled by an office assistant and not be expensive. Do you know of any book or literature treating of making permanent records from wax impressions?

A.H.

Telephone receivers, as usually connected, reproduce both ends of the conversation, but it is doubtful whether an intelligible phonogram could be produced in the manner you describe, even under the most favorable conditions. The amplitude of the vibrations of a telephone receiver diaphragm

transformers available, one can be used for transforming the current up to the meter on test and the other for again stepping down to



No. 756 (a) and (b)

the standard. With this connection, illustrated in Fig. 756 (b), the ratio of the step-up transformer does not affect the acuracy of the test. H.B.T.

757—Flux for Use in Electric Arc Welding—Referring to article on "Arc Welding" in the JOURNAL for January, '08, please advise if any fluxes are used in this method of arc welding, and if so, whether their composition is secret. O.P.L.

This subject was also treated in a subsequent article appearing in the Journal of the American Society of Mechanical Engineers for January, 1912, p. 51. Under the heading "Filler and Flux," p. 55, is the following:

"106. When welding steel and wrought iron the filler may be cast iron or malleable iron, trimmings from boiler plate, bits of locomotive carriage or the like; the cast and malleable iron besides any of the materials. It is permissible to use copper wire or rods of special cast iron which is high in silicon."

"107. While flux is not necessary, as a rule in the welding of steel or pig iron it is known, frequently used in connection with cast and malleable iron and numerous patents have been taken out along this line. A flux considered very good by many practical welders consists of red oxide of iron (Fe_2O_3), 85 to 95 percent; borax, calcined ($Na_2B_4O_7$), 10 to 15 percent."

"108. Fluxes may be used either dry or wet. If dry, they are shaken directly into the weld a little at a time as it is progressing. If wet, a paste is made and the filler rod coated with it and allowed to dry before using." C.B.A.

758—Overload Characteristics of Modern Alternators—*a*—Is there much danger of a modern alternator burning out by heavy overloads or by losing its field, while on the line, or will the inductance of its windings prevent an excessive current? *b*—Is there any up-to-date book, published especially for operators, on the care and operation of modern alternating-current power houses and apparatus? W.S.S.

a—Most manufacturers give guarantees on alternating-current generators to carry from one and a quarter to one and a half times normal load for periods of from one to two hours, with a temperature rise not exceeding 60 degrees C. This, with an initial temperature of from 30 to 40 degrees C., is about the maximum safe temperature for ordinary insulating materials and, if exceeded, the machine may be damaged. The current which a machine, running in parallel with other machines, will take in case the field excitation is cut off will, neglecting the relatively small resistance, depend on the reactance in the armature winding of the machine in question, and also of the machines with which it is in parallel. The value of this reactance depends on the design of the machine and may be such as to allow from five to thirty times normal current to flow at the moment of cutting off the excitation. In case the machine is not cut off from the line, the current will drop to approximately 2 to 10 times the normal current, depending on the characteristics of the machine. This current would undoubtedly roast the machine out if allowed to continue. The circuit breakers should disconnect the machine from the line in such a case, and no damage should result if the windings of the various machines were sufficiently strong to withstand the stresses due to the large rush of current. Most large manufacturers of electrical machines furnish the customer with instruction books covering the principal points to be observed in starting into service and operation of apparatus furnished. These are probably better than any book published on the subject. R.A.M.

759—Operation of Turbo-Generator at Voltage Above Normal—A 5 000 kw turbo-generator is designed for 11 000 volts, but on account of line drop it is desirable to operate above rated voltage. What will be the effect, if any, on the life of the machines, overload capacity and regulation, of operating at 11 500 or 12 000 volts? Are there any objections to such operation? H.N.M.

Such a machine operated at 12 000 volts, 5 000 kw, will give better regulation. The field heating will be approximately the same as at the lower voltage. The armature copper heating will be lower, and the armature iron will run from 10 to 20 percent hotter. The overload capacity will be approximately the same. The effect on the life of the machine will depend on whether or not the above increase in armature iron temperature will bring it to a point where the coil insulation will be damaged. With a machine operating at 40 degrees C rise, the increase in operating temperature would not be dangerous. In general, it is not desirable to operate a machine at a higher voltage than that for which it was designed. More definite information regarding the performance of the particular machine under the stated conditions could probably be obtained by referring the matter to the manufacturer. R.A.M.

760—Cleaning Motors With Compressed Air—Is the use of compressed air in cleaning out motors or generators injurious, and why? I have been using it for a few years at a pressure of 50 to 100 pounds, according to the density of the dirt, but recently a number of people have told me that this practice would ruin the insulation, and that it would be better to leave the dirt in the machines than to blow it out in this way. F.S.

There are two serious objections to the promiscuous use of compressed air for cleaning out motors and generators; first, the mechanical injury to the insulation from the use of excessive air pressure; and, second, the introduction of moisture, present in the compressed air, into the windings of the machine. The governing of the first condition must be left en-

turely to the judgment of the operator. The pressure at which the air can be applied without doing injury, will depend upon the mechanical strength of the insulation. Extreme care should be exercised not to apply a pressure that will produce any loosening or fraying out of the insulation or that will in any way change its condition. While no definite rule can be formulated owing to the wide range of conditions, for the average winding, if well taped and sealed, a pressure of 100 pounds should not prove detrimental, provided the air outlet is not brought within one foot from the winding. The second objection arises from the fact that compressed air, as ordinarily used, always contains more or less moisture. This moisture is deposited on the windings of the machine and, if present in any quantity, may cause serious trouble. Compressed air lines for this purpose should always be thoroughly drained and wherever possible some additional dehydrating process should be used for removing the moisture from the air. If the insulation is not well sealed over the coils, the air at high pressure may drive conducting dirt inside the insulation and eventually cause trouble. B.D.K.

761—Changing 500 Volt Motor For 220 Volt Service—It is desired to change a one hp, 500 volt, two pole motor, which is at present wound with single parallel or lap winding, for 220 volt service. There are 20 armature slots and 40 commutator segments. The brushes cover 1.75 bars. Could a double parallel winding be used, or could two coils be put in parallel in each slot and every other commutator bar short-circuited. What size of brush should be used in either case, and how many bars should each cover? I.B.

There are two methods of accomplishing the desired result namely, by rewinding the armature or by simply reconnecting the present winding.

The former, though involving more labor, would unquestionably give the better results. In this case the number of coils in the armature and the connections to the commutator should remain the same as at present, but the number of turns in each coil should be only half the present number. In case the present number of turns per coil is not divisible by two it would probably be best to make the number of turns per coil equal to (present number — 1) ÷ 2. The armature could be rewound with a conductor of double the cross-section of the present conductor, or with the same size as at present, using two conductors in parallel. In using the second method if the double lap winding is used, either the leads of the two coils lying in the same slot, or the commutator bars to which they connect should be connected together so as to give virtually only twenty commutator bars instead of forty. Failure to connect the coils or bars in parallel may result in an unequal division of the current between the two windings and cause the commutator to blacken. The size of the brush need not be changed unless the current density under the brush is excessive with the new arrangement, say in excess of 40 to 50 amperes per square inch. In case the current density becomes high enough to cause poor commutation, special brushes may be obtained which will permit a higher current density than the figures given above. In addition to changing the armature winding, the shunt field coils should also be connected in parallel instead of series. Under the new conditions the motor will probably run about ten percent lower in speed than originally. See also No. 274, Sept. 1909. H.C.W.

CORRECTION.

In the May, 1912, installment of the articles on "Single-Phase Commutator Motors," by Messrs. Hellmund and Smith, the following corrections should be noted. As *Er* varies with the current and speed, the first sentence on page 425 should read, "Since the flux in the commutating pole remains unchanged, the voltage *Ei* will remain unchanged, and the voltage *Er* will be doubled, if it be assumed," etc. The fourth sentence should accordingly read, "In this case the voltages *Ep* and *Er* are reduced to half the value shown in Fig. 4, while *Ei* is unchanged.

PERSONALS

Mr. J. W. Fraser, assistant chief engineer of the Southern Power Company, has resigned to assume charge of the erection, for the British Westinghouse Electric & Mfg. Company, of a 70 000 kilowatt hydroelectric plant in Tasmania, Australasia, to be operated by the Hydroelectric Power & Metallurgical Company.

Mr. F. R. Fortune has been appointed to the newly created position of general sales agent of the Cooper-Hewitt Electric Company. His headquarters will continue to be in Pittsburgh.

Mr. Norman Macbeth will resume his individual consulting illuminating engineering practice, having resigned as illuminating engineer of the Westinghouse Lamp Company. Mr. Macbeth was formerly illuminating engineer of the Welsbach Company, Gloucester, N. J. Mr. Macbeth will maintain offices in New York City and Philadelphia.

Mr. Cecil P. Poole, editor-in-chief of *Power* for the past seven years, has resigned to take up consulting engineering work in partnership with Mr. Lamar Lyndon, of 60 Wall St., New York City. Mr. Poole will have charge of the southern branch office at Atlanta, Ga.

Mr. Dudley A. Bowen, of the detail and supply engineering department of the Westinghouse Electric & Manufacturing Company, at East Pittsburgh, has recently been transferred to the New York sales office.

Mr. Charles F. Gray, formerly of the erecting department of the Canadian Westinghouse Company, is now engaged in consulting engineering work with offices in the Empress Block, Winnipeg, Manitoba.

Mr. Edward K. Price has been appointed advertising manager of the Standard Underground Cable Company, of Pittsburgh, Pa. For the past two years, Mr. Price has been engaged in agency work with G. P. Blackiston, of Pittsburgh, and previously was for a number of years in the publicity and in the sales department of the Westinghouse Electric & Mfg. Company.

Mr. C. E. Clewell, of the detail and supply sales department of the Westinghouse Electric & Mfg. Company, East Pittsburgh, has accepted a position in the electrical engineering department of Sheffield Scientific School of Yale University.

Mr. C. W. Hookway, at one time connected with the Montreal office of the Canadian Westinghouse Company, has again accepted a position with the same company in the capacity of salesman connected with the Toronto office.

Mr. Stanley Stroud, formerly of the sales school of the Westinghouse Electric & Mfg. Company, and for some time correspondent in the Toronto office of the Canadian Westinghouse Company, has been promoted to salesman in connection with the same office.

Mr. H. A. Cooch, at one time engineering apprentice with the Westinghouse Electric & Mfg. Company, East Pittsburgh, and later with the University of Toronto, has accepted a position in the Toronto office of the Canadian Westinghouse Company.

Mr. H. A. Rapelye, heretofore connected with the Pittsburgh office of the Westinghouse Machine Company, has been chosen to succeed Mr. E. D. Dreyfus in the publicity work of the Westinghouse Machine Company at East Pittsburgh.

Mr. S. G. Meek, who has been associated for some fifteen years as special representative of the H. W. Johns-Manville Company, in the electrical department, has been appointed assistant general manager of the department.

Mr. G. W. Canney, manager of the service department of the Westinghouse Electric & Mfg. Company, is making a tour of the branch offices of his department.

Mr. J. B. McCarthy, until recently in the erection department of the Canadian Westinghouse Company, is now engaged in sales work in the Toronto office of the same company.

The *Southern Textile Bulletin* for May 30 and June 6 contains a reprint of the article on "Care and Operation of Commutators," by Mr. W. A. Dick, from the JOURNAL for May.

N. E. L. A. CONVENTION

While the total registration of about 1,500 at the Seattle convention of the National Electric Light Association, held June 10-14, was less than that of the previous year, the meeting will be remembered as one of the most successful and interesting in the history of the organization. The various sessions were held in the Seattle Armory, which was also used as the exhibition quarters. The local electrical interests were lavish in their efforts to entertain the visitors. The program was followed out substantially as outlined in the last issue of the JOURNAL. The following officers were chosen for the ensuing year: President, F. M. Tait, Dayton, O.; first vice president, J. B. McCall, Philadelphia; second vice president, H. H. Scott, New York; treasurer, W. W. Freeman, Brooklyn; executive committee (3 years), John A. Britton, San Francisco; C. E. Goesbeck, San Diego; Charles A. Stone, Boston; (1 year) R. S. Orr, Pittsburgh. In the power transmission section the following officers were elected:—Chairman, W. N. Ryerson, Duluth; first vice chairman, D. B. Rushmore, Schenectady; second vice chairman, P. M. Lincoln, Pittsburgh; secretary, Farley Osgood, Newark N. J.

The fifth annual convention of the Pennsylvania Electric Association will be held on September 4, 5 and 6 at the Bedford Springs Hotel, Bedford Springs, Pa. Mr. R. S. Orr, general superintendent of the Allegheny County Light Company, Pittsburgh, is president of the Association.

The sixth annual convention of the Illuminating Engineering Society will be held at the Hotel Clifton, Niagara Falls, Ontario, September 16-19. The final program has not yet been announced, but will include a number of notable papers embodying the results of recent investigations.

NEW BOOKS

"Electrical Injuries." Charles A. Lauffer, A.M., M.D. Flexible cloth cover, 4 inches by 6½ inches, 77 pages. Published by John Wiley & Sons, New York City. Price 50 cts.

The treatment of flash and contact electrical injuries is primarily for the physician, but it is the duty of all to be familiar with the essentials of first aid in case of accident, especially where an electric shock has resulted in loss of consciousness. This convenient little handbook, designed primarily for the use of practical electrical men, contains information compiled in most admirable form covering not only the treatment of electrical injuries, but a comprehensive discussion of their causation and prevention. The very lucid and complete description of the prone pressure method of resuscitation from electric shock in case of suspended respiration places this book in the category of those which should be read by all; for who knows when the occasion may arise that a working knowledge of a suitable method of applying artificial respiration will serve to save the life of some person who has met with serious accident? The author indicates that the method of resuscitation described is applicable not only in case of electric shock but with equal success in case of drowning or asphyxiation from whatever cause. This material is most timely in view of the fact that the resuscitation commission recently appointed jointly by the National Electric Light Association, and the American Medical Association has recommended the prone pressure method (due to Prof. E. A. Schaefer of Edinburgh) for adoption. The discussion of various features entering into the physiology of electrical injuries is given added importance by quotation from various authorities and includes interesting matter regarding the method employed in criminal electrocutions and various phenomena accompanying them. The author is to be commended for the evident care with which the text has been prepared to place all facts, and directions for treatment in administering temporary aid in case of accident, in language free of technical medical terms and therefore entirely intelligible to all readers. It is also most instructive to have the subject supplemented by notes on important fundamentals of minor surgery and infections, and a chapter on the conservation of the bodily resources. This last chapter, if not all of the book, could be read with profit by young and old. The lists of questions on the subject matter makes the book a valuable one for student readers, and serves to discover many less evident merits of the text. The purpose of the author and publishers is evidently to offer the book at such a moderate price that it will be accessible to all.

A Time Saving Proposition

A common method of indexing engineering publications is by the use of semi-annual alphabetical lists of articles published during the preceeding six months. Any one who has occasion to refer to back issues of technical periodicals realizes the time-wasting features of such a method. For instance, even considering one of the younger publications such as the Journal, this method would mean **16 indexes** to be referred to in order to locate references on any desired subject. By the use of

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are thus more valuable than those of other publications because all of the material is immediately available. The sale of over **9 300 Bound Volumes** is good evidence that this feature of the Journal is appreciated, as well as the high-grade, practical nature of the articles, now totaling 6 500 pages.

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NEW BOOKS

"The Application of Hyperbolic Functions to Electrical Engineering Problems"—A. E. Kennelly. 278 pages, 99 illustrations. Published by the University of London Press, Ltd., London, England. Price, $2.25.

This work is based on a series of five lectures given by the author at The Institution of Electrical Engineers for the University of London. Discussions are given on applications of hyperbolic functions to direct current lines of uniform resistance and leakage in the steady state, equivalent circuits of conducting lines in the steady state, regularly loaded uniform lines, complex quantities, the process of building up the potential and current distribution in a simple uniform alternating-current power transmission line, the application of hyperbolic functions to alternating-current power transmission lines, the application of hyperbolic functions to wire telephony and telegraphy, etc.

"Alternating-Current Design." Julius Frith. 118 pages; 27 illustrations. Published by D. Van Nostrand Company, New York City. Price $2.00.

This book covers briefly the design of alternating-current generators, induction motors, transformers and transmission lines, mainly by numerical examples. There is a brief discussion of some of the principles involved, but this is necessarily incomplete and intended to supplement the subject matter of other similar books, chiefly a companion volume on direct-current design by Cramp. The author has aimed, according to the preface, "to emphasize the inward physical meaning rather than the outward mathematical form," but, according to the text, the design methods advanced are mainly empirical. If the high aim of the preface had been more successfully carried out in the text, the book would be of greater value and interest. Referring to the chapters on generator design, the method of calculating stator slot and rotor pole leakages, and the method of figuring the maximum stator tooth density, are unnecessarily crude and approximate. On the other hand, the discussion of inherent regulation and output constants is good. While the methods of design outlined will, undoubtedly, give results that will check with the actual performance, providing that the designs follow closely those from which the empirical methods have been derived, they will be found entirely inadequate to design generators departing from these proportions and to investigate unexpected results and determine the remedy.

F. D. N.

"Design of Electrical Machinery," Vol. I. Direct-Current Dynamos—William T. Ryan. 109 pages, illustrated. Published by John Wiley & Sons, New York City. Price, $1.50.

This is the first of a series of college text-books by Prof. Ryan, of the University of Minnesota. It is divided into three chapters, the first giving fundamental general principles and the last two a number of detail illustrative designs. The design in the third chapter is that of a 300 kilowatt direct-current generator.

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"Engineering Law: The Law of Contract"—Alexander Haring, 508 pages, published by the Myron C. Clark Publishing Company, Chicago, Ill. Price, $3.00.

This book is a valuable epitome on the elements of contract law which affect the work of the engineer. The subject is divided into its four main branches, which are properly defined and ramified so that all essential matter may be comprehended. The author by profession is both an engineer and a lawyer and therefore has been in a position to adjust the contents of his book not only to the needs of the engineer, but at the same time his work is fundamentally correct legally. A compromise between the text-book method and the case system has been made and it is believed that this should be of the greatest value to the engineer. The references and decisions constitute the major part of the book's contents. The vital feature of each case included is appropriately designated. Engineers will welcome the book, as an adequate conception of the matters treated therein may be considered of great value to them with the broad duties men in this profession are now assuming. E.D.D.

"Third Annual Report of the Board of Supervising Engineers, Chicago Traction." 535 pages. Published by the Board.

The board is made up of representatives of the city of Chicago, the Chicago Railway Companies and Bion J. Arnold, chairman. As in previous years the report is voluminous and detailed. An idea of the immense scope of the work of the Board may be gathered from the statement that the cost of rehabilitation work to date is in excess of forty-two million dollars.

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The Winnipeg Branch of the H. W. Johns-Manville Company, owing to their fast increasing business in Asbestos, Magnesia and Electrical supplies, has found it necessary to move into new quarters at No. 92 Arthur street, Winnipeg. This is a six-story and basement building, 100 feet deep and 50 feet wide, and will be occupied throughout by the Company's offices and store rooms. By reason of this move, a much larger and more complete stock of goods will be carried on hand than heretofore, and a larger force will be employed to look after the company's interests.



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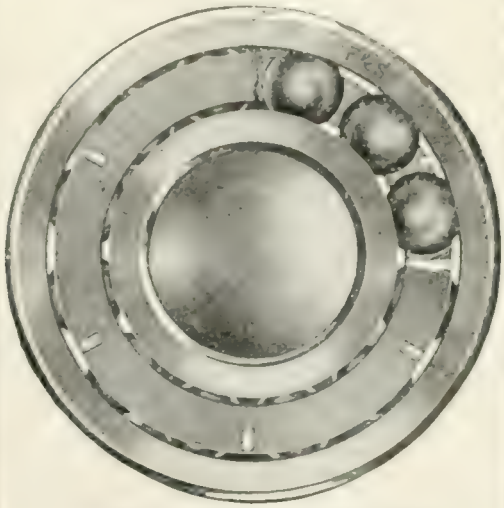
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TYPEWRITER CONSOLIDATION

The sales forces of the Remington, Smith-Premier and Monarch Typewriter Companies have been consolidated.

In view of the enormous development of the office equipment industry in recent years, which owes its birth and growth to the typewriter, the consolidation of the sales forces of the three machines under one management was simply a business recognition of the unquestioned advantages which must necessarily be derived from the operation of one highly efficient organization.

The Executive Staff of the greater organization will consist of the active leaders of the three original companies. In the filling of the other managerial and selling positions, it has already become evident that the full selling strength of these three typewriter organizations will be utilized from the very outset.

The consolidation is the first step of expansion for a campaign more aggressive than ever. There will soon be opened in the United States many new branch offices to include many cities and towns not hitherto covered by the local office of any typewriter company.

The introduction of the new Remington sales policy comes at a propitious time. The record during the past year of all of the three typewriters involved in this union of forces constitutes of itself an assurance of a great future. The Remington, Smith-Premier and Monarch typewriters each did a business last year which surpassed every previous record.

The Nelson Valve Company, of Philadelphia, has recently published a new catalogue "S" illustrating and describing its latest lines of valves. A number of changes are indicated from the general catalogue issued in 1909. An interesting part of this booklet is the portion devoted to an illustrated description of the methods of manufacture and testing of Nelson valves.

The Norma Company of America, 20, 22 and 24 Vesey street, New York City, have published two circulars describing their lines of ball-bearings and roller-bearings. This company makes a specialty of ball-bearings for small motors, magnetos, electric ignition apparatus, speed indicators and other small machinery operating at high speeds.

THE
ELECTRIC JOURNAL

Vol. IX AUGUST, 1912 No. 8

The Boston Convention of the A. I. E. E.

What constitutes a successful Convention of the American Institute of Electrical Engineers? Is it attendance? Then the Boston Convention was certainly highly successful for, barring the Convention at Chicago last year, this Convention had the highest registration of any in the Institute's history. Chicago set the high water mark in attendance last year with a registration of 965, and Boston came within less than two score of the same figure. Both these figures are something like double the registration of any other Convention in the Institute's history. One of the things that makes attendance at an Institute Convention so agreeable is that there one meets his friends from all over the country. It is the common meeting place of all men electrical, and the greater the attendance the wider will be the circle of friends with whom one comes into contact. In attendance, therefore, and all that goes with it, we can put down the Boston Convention as a successful one.

Is it in the completeness of the entertainment programme? Here again the Boston meeting will refuse to give way to any preceding Convention. The local committee under the able leadership of Mr. Charles L. Edgar left nothing to be desired in the way of entertainment for attending members. Theatre parties, concerts, auto trips, luncheons, boat rides, and other forms of entertainment were provided, not only for the ladies attending the Convention, but also for the men whenever they could find a moment's respite from the sterner duties of the week. In its entertainment, therefore, the Boston Convention may certainly be set down as a successful one.

Is it in the brilliancy of the annual banquet? Surely Boston shines on this score. Never was there a more suave toastmaster than President Dunn. The toasts were responded to in a brilliant manner and the evening reached its climax in the presentation of the Edison medal to Mr. George Westinghouse. This occasion

was made all the more memorable by the fact that the presentation of the medal was made by Prof. Elihu Thompson, the first recipient of the medal. Nothing could show more thoroughly the harmony which has, in these latter years, taken the place of the controversies of twenty years ago over alternating current versus direct current, than this presentation to Mr. Westinghouse, the exponent of the alternating-current system, of an *Edison* medal by Prof. Thompson, now prominently identified with those who took the opposite side of that argument, and to make the anamoly more complete, the reason for the award of the medal to Mr. Westinghouse is his work in the development of the alternating-current system. In this feature, there can be no question but that the Boston Convention was certainly a successful one.

Is it in the length of the programme of papers? The fact that the numbered events on this programme reached a total of sixty, thirty-two of them being scheduled for the last day, answers this question. By the device of parallel sessions, a total scheduled time of twenty-four session-hours (if such a term may be accepted) was obtained for these scheduled events or an average of just 24 minutes per event. Thus in length of programme, the Boston Convention not only reached but *over-reached* the "Acme of perfection." Whatever criticism is to be made against the Boston meeting will undoubtedly be made upon this score. Mere volume of material presented does not make a successful Convention, and to the minds of many, the overcrowded programme was the only fault in an otherwise highly successful meeting. The papers programme of a Convention of this kind becomes interesting, and therefore successful, not entirely on account of the presentation of papers, but also on account of the *interchange of ideas*, for which the presentation of a paper simply serves as an introduction. If, as at Boston, the programme is so crowded that there is no time for this interchange of ideas, the result not only becomes a disappointment, but also a failure to the extent that the interchange of ideas does not materialize.

However, in spite of the crowded condition of the programme there were certain features that stand out in relief. Two joint sessions, one with the Illuminating Engineering Society and another with the Society for the Promotion of Engineering Education gave concrete evidence of that type of cooperation which should be the watchword of all engineering societies. May there be more of such cooperation at future conventions.

Another feature of this Convention that merits special note, is the symposium upon the methods of electrical measurement. Eighteen papers covering many phases of this subject were presented to two successive sessions of the Convention. Probably the most active and interesting discussion of the whole Convention was brought out during these two sessions. Here again, the crowded condition of the programme prevented the development of the subjects as they should have been. The committee having this matter in charge, however, should be congratulated upon obtaining so many concrete ideas in brief form, as were presented to these sessions.

In planning future Conventions, it would be well for those in charge to note the short-comings of the Boston Convention as well as its features of success. P. M. LINCOLN

Methods of Testing Large Alternators

With the rapid industrial development towards very large electric generator units, it has become impossible even for the largest electric manufacturing companies to test these machines under load, and the various substitute methods discussed by Mr. F. D. Newbury in this issue of the JOURNAL thus were devised: the zero power-factor method, the open delta method, and various compromise tests consisting of open circuit runs at over voltage and short-circuit runs at over current.

These and all other no load tests necessarily are subject to the limitation that the field distortion of the amature reaction of the energy current, and whatever losses may result from this distortion, cannot be introduced in the test since even in the zero power-factor method the armature reaction, while present, is not distorting but demagnetizing. Experience, however, has shown that such losses resulting from field distortion are either absent, or so small as to be practically negligible.

The zero power-factor method is the most satisfactory, but limited by the requirement of additional machine capacity. The open delta method is free from this limitation, but due to the presence of a rotating armature reaction cannot always be relied upon to give correct results, as pointed out by Mr. Newbury, but in this test serious energy losses may occur in the field, and corresponding heating, which would not exist under actual load. Such may be the case when the field contains solid pole pieces, or squir-

rel cage or other damper windings. Even with laminated fields, in some fractional pitch windings with a single coil per slot, pole-face losses, due to a high frequency pulsating armature reaction, may occur in the open delta test.

Compromise tests consisting of separate open circuit runs at over voltage, to get the core heating, and short-circuit runs at over current, to get the coil heating, have the fundamental objection that the temperature distribution, and with it the path of the heat current, differs from that under short-circuit test, which is free from this objection. In large machines, it usually takes many hours to reach stationary temperature, and the temperature change during a quarter hour or so is very small. Instead of having simultaneously voltage and current, as in the full-load test, alternate periods, of short-circuit at excess current, and open circuit at excess voltage, may be run. The excess current and the excess voltage would be chosen so that the average armature I^2R loss, and the average core loss during the open circuit and the short-circuit run equal the values at the rated load. The average power loss, and with it the heating of the machine armature, then should be the same as under full energy load, the only difference being that the core heating and the coil heating occur not simultaneously, but successively. By choosing the alternate periods of open and short-circuit run sufficiently short, such a compromise test should give correct results of temperature rise.

In such a load test, in which periodically open circuit and short-circuit alternate in such a manner that the total loss during each period is the same as at full load, obviously it is not necessary to divide the time of each period equally between open and short-circuit run, but any division of time would be practicable, within a wide range. For instance, alternate short-circuit runs of ten minutes at seventy-three percent above rated current, and open circuit runs of twenty minutes at such over voltage that the iron loss is fifty percent above that at full-load (less whatever iron loss occurs during the short-circuit period).

In many cases it then may be possible so to choose the proportion between the open circuit and the short-circuit part of each period, that the average I^2R loss in the machine field during the two periods, equals that at the rated full load, and in this case such a combination of periodically alternating open circuit runs at over voltage and short-circuit runs at excess current would give,

in the armature as well as in the field of the machine, an average heat production, and with it temperature rise, equal to that at the rated energy load. CHARLES P. STEINMETZ

Decrease in Cost with Improved Product

In these days, when so much is being said and written about the higher cost of necessary things, the electrical manufacturer should feel great pride. While the quality of generators, rotary converters, transformers, motors, incandescent lamps and hundreds of other electrical devices has been greatly improved, the price of these commodities, through the brilliant work of the designers and the factory men, has greatly diminished, in spite of the increased cost of labor and raw materials. At the same time the efficiency of all classes of electrical apparatus has been increased, the life of dynamos, transformers, etc., has been extended and the reliability of all such devices improved. The users of electrical machinery and appliances have, from experience, come to depend on such machinery as they depend probably on no other general class of apparatus in constant use.

H. D. SHUTE

Consolidated Electric and Heating Plants

The project of utilizing exhaust steam from a central electric plant, for district heating has long been an attractive one from a theoretical standpoint. The practical difficulty has been to discover a steam engine suited for the very unusual demands imposed by the heating service.

Such an engine must be able to operate against back pressures up to ten or fifteen pounds, and if the profits from the heating are not to be eaten up during the warm season, it must be capable of operating condensing with as high efficiency as though back pressures had never been contemplated. The designer of reciprocating engines has always regarded this as a discouraging if not altogether hopeless problem.

The "Bleeder" turbine—a comparatively recent development in prime movers—is happily, oblivious to all of the variations in conditions of back pressure that are associated with the operation of an exhaust heating system. It automatically makes the best of these conditions as it finds them, whether they are changing every minute or whether they remain constant for months. If all

of the working steam has to be delivered to the heating system against a considerable back pressure, there is no balking. If only a portion of the working steam is required for heating, the bleeder turbine turns the surplus to good account in its low pressure section, exhausting into a condenser. If no steam at all is required for heating, then the turbine operates as a complete expansion engine just as efficiently as though its special features were entirely absent.

Now that the prime mover is expunged from the list of things to worry about, the combined electric and heating plant takes on a renewed interest. The article by Mr. E. D. Dreyfus in this issue of the JOURNAL is therefore peculiarly timely. The author's treatment of his subject is refreshingly novel and interesting. He analyzes the effects of climate, changing seasons, load curves, etc., on the total station demand, and points out the line of investigation to follow in determining whether or not any particular set of local conditions will justify the combination of a heating service with an existing or proposed electric plant.

The paper can be read with much profit by anyone who is interested in this subject, which is becoming more and more a matter for thoughtful consideration. H. E. LONGWELL

Standard Methods of Testing

Attention is called in particular to the editorial by Dr. Steinmetz on Mr. Newbury's article in this issue. For many years Dr. Steinmetz has been a leading member of the standardization committee of the American Institute of Electrical Engineers and he is an enthusiast on all matters which may properly be included under the subject of standardization. In the Institute standardization committee meetings during the past year, the question of standardizing methods of testing was under discussion a number of times. Both Dr. Steinmetz' editorial and Mr. Newbury's article are timely in showing the need of standardization in one particular class of apparatus. This is simply indicative of the situation to a greater or less extent as regards all classes of apparatus. B. G. LAMME

COMBINED CENTRAL HEATING AND ELECTRIC PLANTS*

EDWIN D. DREYFUS

BOTH the significant growth of the National District Heating Association and the representative public service companies affiliated therewith attest the better credit now being accorded the central heating institution. In the main this has logically come about through more skilled engineering, better materials, properly laid street mains, adequate rates, wisely selected systems and more proficient management. Evidently there are natural limitations to the installation of heating systems, but within the sphere where such systems will be found profitable, there still remain opportunities for improving upon existing methods, particularly where the heating system is a component part of an electric lighting plant.

The operating of a heating plant singly is only attractive under favorable circumstances. Electric stations, operating independently, are successful in the majority of cases; but by effectively combining the two, very fair returns should accrue from conjoint operation of such properties. The economies resulting from one management, one boiler plant replacing two, greater earning power derived from one pound of steam, higher grade of labor and engineering, and a general saving in operation and investment, establish good reasons for the reversal of the unsatisfactory conditions at first experienced. The showing of many companies now conducting both forms of utilities, demonstrates the truth of this statement.

With constantly increasing demands being made upon central station companies, it behooves them to make proper preparation accordingly, and this paper is undertaken to present some new developments in prime movers, more particularly in the steam turbine field, whereby it will be possible to effect material improvement in efficiency of the consolidated electric steam heating plant and to provide means for comparing different types of plants. One of the new developments is the construction of an automatic type of turbine unit, designed to supply both electric power and exhaust steam efficiently. The variables encountered in both the heating and

*From a paper presented before the National District Heating Association, at Detroit, Mich., June 27, 1912.

electric load make such an automatic device all-important, and while temperature fluctuations and hourly variations in central station loads, peaks at dusk and diminishing demand throughout the remainder of the day, are now matters of common knowledge, the presentation of certain facts relating thereto, will undoubtedly serve to imbue the mind of the central station operator with a keener appreciation of these elements. They are, therefore, taken up in considerable detail and graphic charts employed freely.

TEMPERATURE FACTORS

As this paper is concerned principally with heating requirements, a study of the seasonal, daily and hourly variations in some

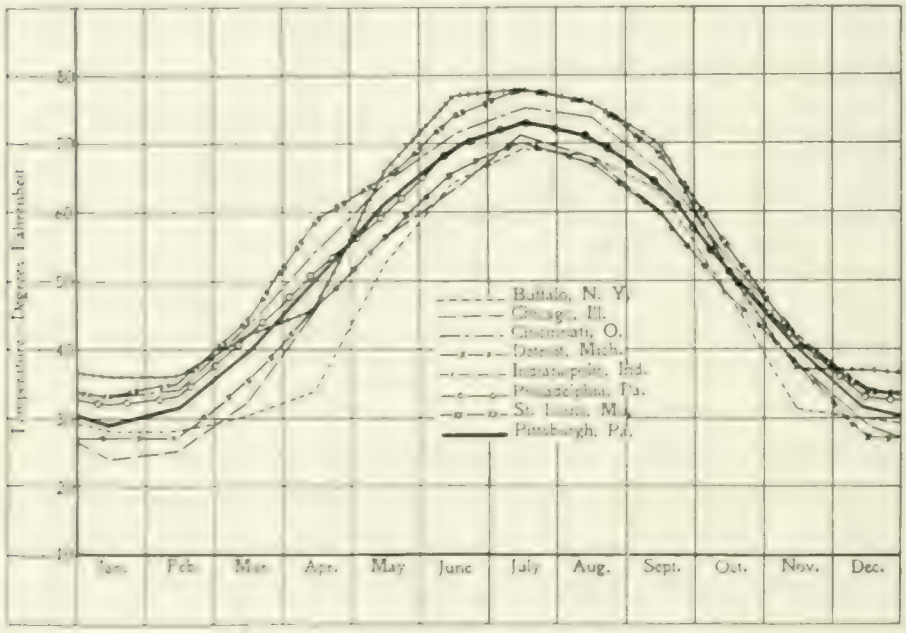


FIG. 1—MONTHLY TEMPERATURE CURVES

Mean temperature for each month compiled from observations of the U. S. Signal Service and Blodgett's Climatology of the United States.

typical latitude where a heating plant may be installed, will be taken up first. The monthly temperature for the year from the U. S. Signal Service and Blodget's Climatology for eight first-class cities of this country are reproduced in Fig. 1. Although data of the large cities is used, it is not expected that developments are mainly to arise in such places. On the contrary, smaller cities offer better opportunities as the areas covered are less, and condensation and friction losses may be better controlled. However, the records of the larger cities, which are more readily obtainable, are given simply as an index of the sections centering about them.

Pittsburgh climatical conditions, with possibly the exception of a small difference in humidity, proves itself to be a fair average between latitudes 38 and 43 degrees, which embrace the territory investigated. This is shown more clearly in Fig. 2 where the average of all these curves is shown by the dotted line, while a twenty-year average for Pittsburgh is represented by the heavy line. In work of the kind here presented, it is necessary of course to make a broad compass of conditions in order that we may not be misguided by exceptional records.

The analysis of these conditions is no wise complete if we rest content in arriving at our results by using simply the monthly

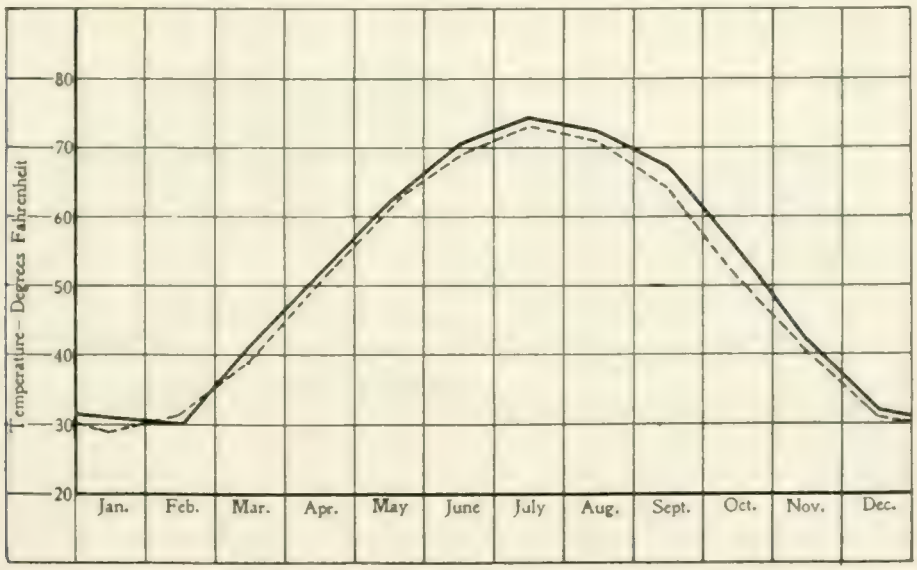


FIG. 2—MONTHLY TEMPERATURE CURVE AT PITTSBURGH, PA.

The dotted curve is based on U. S. Signal Service observations and Blodgetts's Climatology of the United States and represents an average of the atmospheric temperatures in Buffalo, Chicago, Cincinnati, Detroit, Indianapolis, Philadelphia and St. Louis.

The heavy curve is based on an average of 20 years (1891-1910), of observations by the U. S. Weather Bureau at Pittsburgh, Pa. This curve is the one used in the accompanying calculations.

figures. Effects of not only daily changes, but the hourly variations as well, must be properly examined. Hence the records of the U. S. Weather Bureau at Pittsburgh have been consulted, and twenty-year averages have been plotted in Fig. 3.

ACTUAL STEAM CONSUMPTION OF HEATING SYSTEMS

The exhaust steam demand through the year will depend upon the extent and character of the heating system. It is unsafe to generalize on these matters, and it will require that some specific

example be followed through; i.e., a station be studied in which the electric and heating load characteristics may be proportioned with a fair measure of certainty. Although some arbitrary assumptions may be necessary, there is ample existing data to guide us in our judgment in this work. An assumed station has been laid out accordingly (see Fig 15) to contain three 1 000 kilowatt automatic bleeder turbines and two 1 000 kilowatt standard condensing turbines. This station is intended to serve a maximum average heating demand of 65 000 pounds of steam per hour, and an electric peak of 4 600 kilowatts. These demands occur during different months of the year, the high electrical peak in December, and the greatest heating consumption in February.

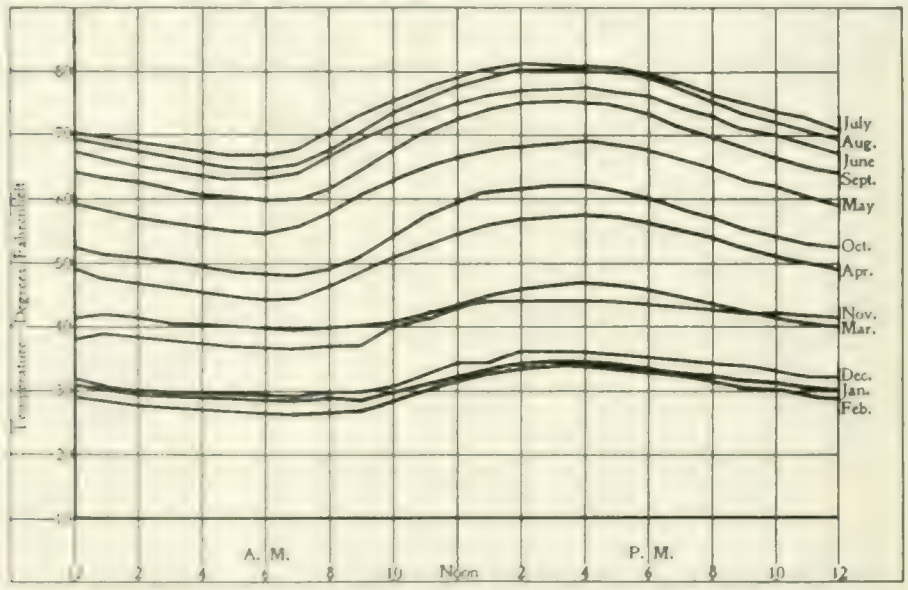


FIG. 3—HOURLY ATMOSPHERIC TEMPERATURES AT PITTSBURGH, PA.
Monthly averages for 20 years (1891-1910), of observations by the U. S. Weather Bureau.

The ratio of the maximum kilowatts to heating steam demand of the plant under consideration, is 1 to 14.2. Manifestly this may be greater or less, depending upon the locality and the extent to which the electric and steam business has been developed, remembering also that residential heating may become a large factor in increasing the ratio. From the facts at hand, this determination for an ideal case seems justly warranted. Any deviations from such a relationship as obtains herein will only go to emphasize the value of *extreme flexibility* in the type of generating units which should constitute principally the modern power station located in towns or cities where distribution of steam heat has its fitting place.

According to "Central Station Facts and Factors"* and from private records, the conditions under discussion apply approximately to a city of about eighty thousand to one hundred thousand population.

Next in order is the derivation of the hourly steam consumption for different outside temperatures (standard inside room temperature of 70 degrees F. understood) and these are arrived at empirically from available data, as given in Fig. 4. It should be noted that ordinarily the amount of steam consumption in the heating system, does not vary materially from hour to hour throughout the day. Mr. F. C. Chambers, in his paper before the National District Heating Association, last

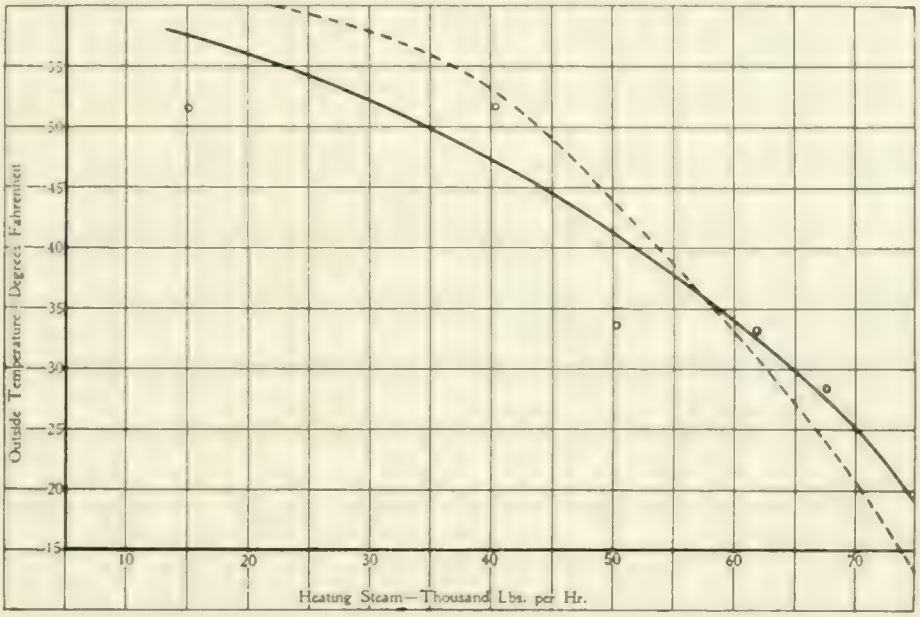


FIG. 4—OUTSIDE TEMPERATURES AND STEAM REQUIRED FOR CENTRAL STATION DISTRICT HEATING

The dotted curve is derived from a curve given by F. C. Chambers, on page 82 of the Proceedings of the National District Heating Association for 1911.

The circles represent points given by a 6 000 kw Central Station in Illinois.

The full line represents an average curve assumed for the accompanying calculations.

year, showed that such conditions prevail, and this is largely confirmed by another example in the report of the Committee on Steam Heating of the National Electric Light Association, read at their recent Seattle convention. The relationships ap-

*A paper presented by Mr. J. R. Cravath before the Ohio Electric Light Association, July, 1910. See *Electrical World*, Aug. 4, 1910, p. 246 also *Electrical World*, Apr. 27, 1911, p. 1040.

pearing in these curves, form therefore, a basis for the subsequent calculations.

PRESSURES IN THE HEATING MAINS

As the outside temperature decreases and the steam consumption in the heating system changes correspondingly, the pressure at delivery from the power house must be raised to overcome the friction losses and effect of condensation which increases as the demand becomes greater. A schedule of pressures is usually established, and the curves in Fig. 6 will indicate suitably the proportionate pressures that should exist at the outgoing feeders from the power house for different outside temperatures.

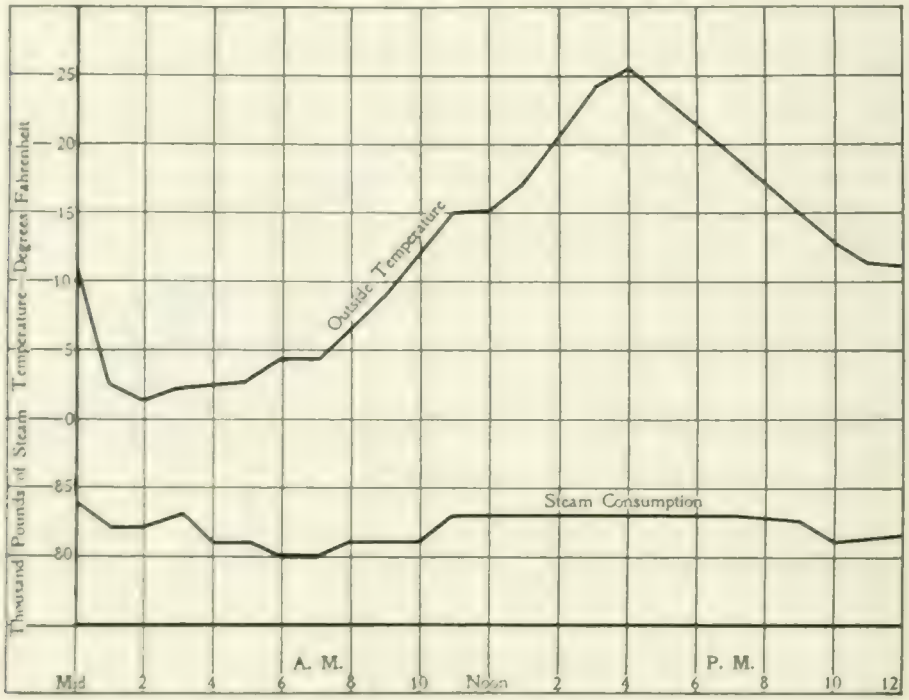


FIG. 5—STEAM CONSUMPTION AND OUTSIDE TEMPERATURES FOR JAN. 4, 1911, AT SPRINGFIELD, ILL.*

These figures are somewhat arbitrary, as it is obvious that the absolute pressures in any case will depend upon the size of mains used and their length or lineal equivalent. Usually the pressures are kept at a slightly higher point during the day than at night.

This phase of the problem introduces another feature which must be taken into account in the design, or else in the method of operating the prime mover. The less the machine will be disturbed or affected by such conditions, the greater the safety of the plant,

*This curve is from a paper by F. C. Chambers and may be found on page 81 of the Proceedings of the National District Heating Association for 1911.

because of the smaller liability of accident or derangement due to neglect of such conditions at the proper time.

To illustrate, a Corliss engine may be arranged and regulated so that steam may be bled from the receiver. A high receiver pressure on the engine may frequently be necessary in cold weather at light loads which will cause looping and resulting pounding and may become very serious. This means among other things,that in the engine plant equipped with reciprocating engines, the greatest care must be taken in choosing the proportions, and moreover, corresponding vigilance in operation is required in order to secure the last fraction of economy. The automatic bleeder turbine which is herewith described in detail, is quite impervious in operation to pressure changes, and furthermore the results are accomplished with the

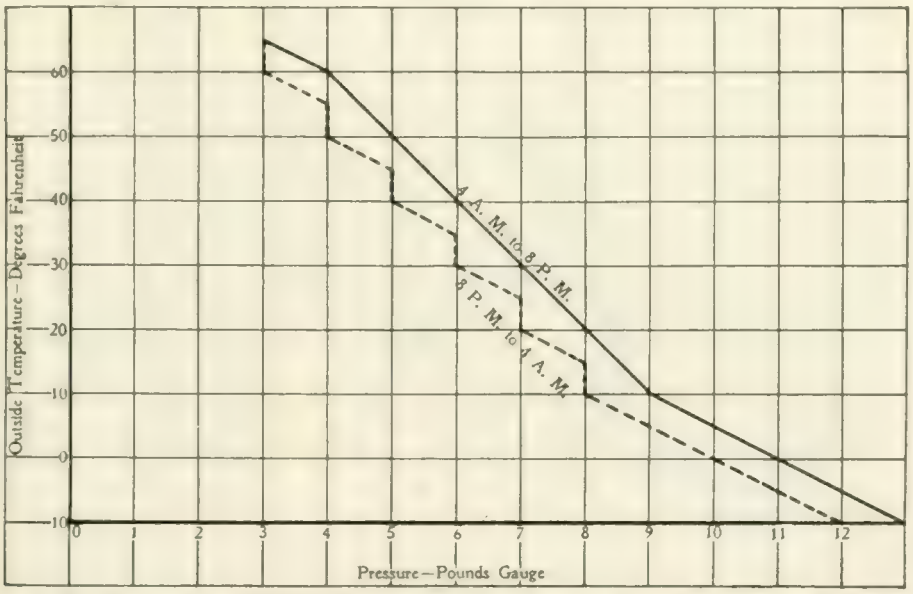


FIG. 6—A GIVEN SCHEDULE OF PRESSURES TO BE CARRIED ON A PARTICULAR SYSTEM OF HEATING MAINS FOR DIFFERENT OUTSIDE TEMPERATURES*

greatest facility. In addition, it is within the bounds of possibility that the pressure valve of the automatic bleeder turbine might safely be provided with thermostatic control where such may be desired to insure uniform service.

NATURE OF ELECTRICAL LOAD

When the probable characteristics of electric load are contemplated, we find there are limitless "permutations and combinations," so to speak. Sporadic curves have been collected and reproduced

*For a more general treatment of the pressures required, see chap. II, "Central Station Heating"—Byron T. Gifford, 1912.

in Fig. 7 which have been compared on a proportionate instead of an absolute scale. Again flexibility becomes the "byword."

The shape of the curves is influenced by the various kinds of loads connected on the system—motors, electric irons and special appliances. Contracts for off-peak service may produce a rather flat load curve, as exhibited by curve *1*. At the present time, this last condition is more of an unusual order than regularly obtains, so for our purpose it has been necessary to gauge the most representative kinds of loads, and curves *8* and *9* for the winter and

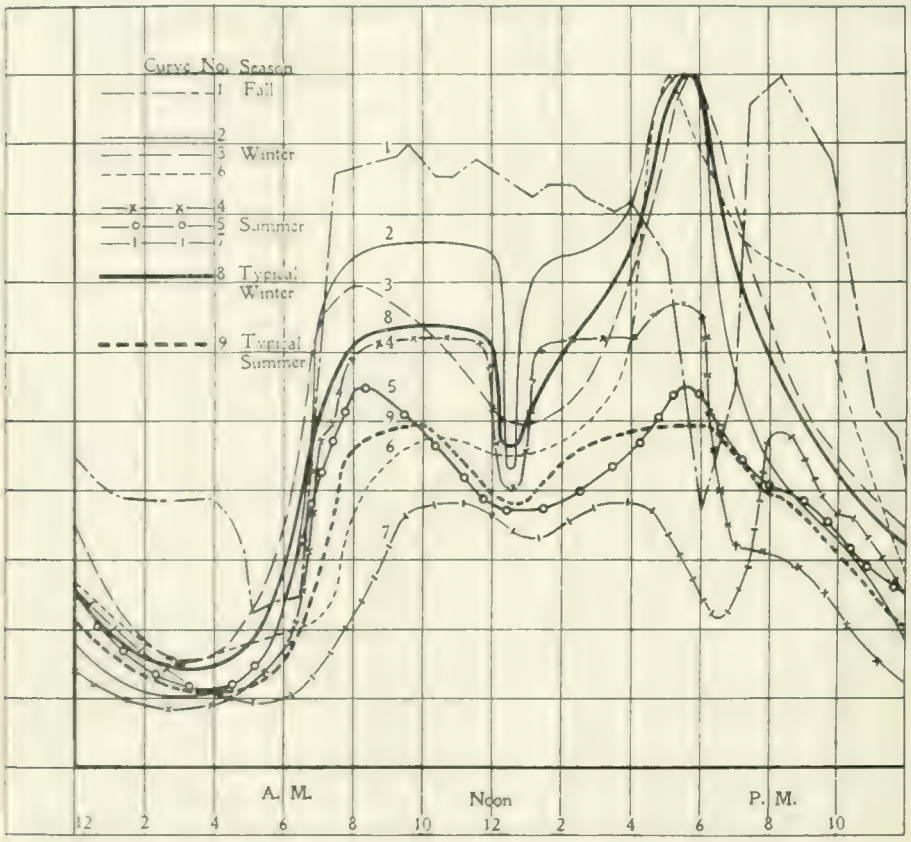


FIG. 7—SOME OCCURRING LOAD CURVES

summer months respectively have been determined upon from our general knowledge of the situation.

TYPES OF STEAM-ELECTRIC UNITS

Reciprocating engines have been used principally where the heating demand was a large factor. They have been simple or compound non-condensing, compound condensing with provision for bleeding from the receiver, or else the plant has consisted of a combination of these types in order to produce the best results for whatever conditions exist and must be met. Compound recipro-

cating engines with moderate cylinder ratios, have been often selected so that the engine may run alternately condensing or non-condensing as the demands may dictate, but it will be plain from Fig. 14 that a large loss of economy will be suffered during the non-heating seasons, as well as during times of light heat demand. Non-condensing steam turbines have been installed in a few cases, as well as condensing steam turbines where steam has been bled from the intermediate stage.

There has been devised within the last two years, a special turbine in which the steam not bled is automatically diverted to the low pressure section. The earlier types of engines and turbines are already well understood, but it will be of advantage to present a full description of this new design.

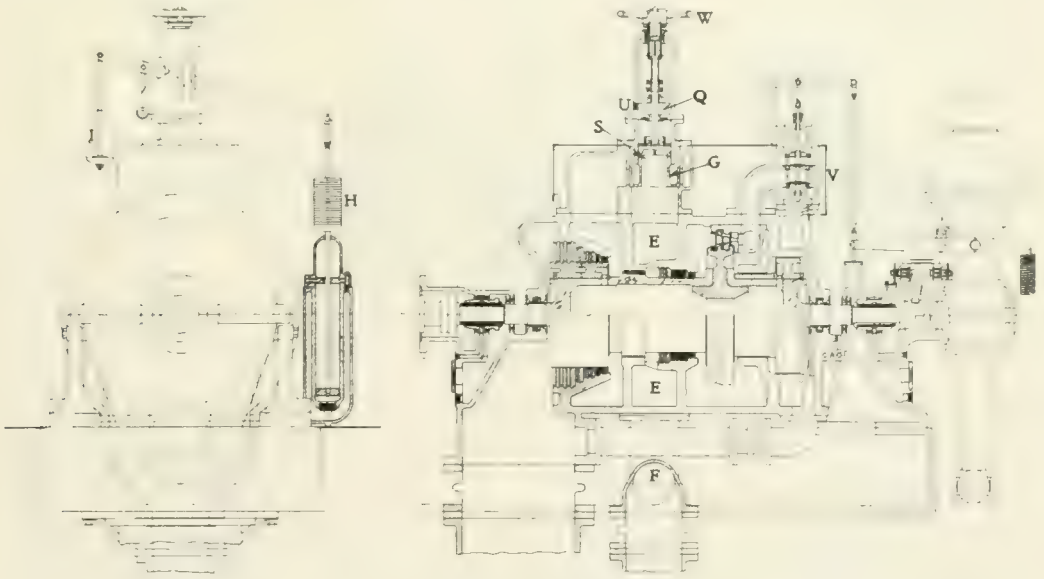


FIG. 8—DETAILS OF AUTOMATIC BLEEDER TURBINE FOR COMBINED ELECTRICAL AND HEATING LOADS

A single flow turbine with automatic bleeder valve designed for moderate sizes, is shown in Fig. 8. It will be seen that the construction closely resembles a standard condensing turbine, the main departure being the locating of a diaphragm between the intermediate and low pressure stages, the flow of steam being regulated by a gravity controlled valve *G*. Live steam is admitted at *U*, and passing through the high pressure and intermediate sections, part is diverted to the heating system through the connection *F*, the surplus passing through the valve *G* to the low pressure section and thence to the condenser. The action of the bleeder valve *G* depends entirely upon the influence of its own weight and the auxiliary or counter-weights *H* and *I* respectively. These consist of

flat cast iron discs resembling the standard scale weights. Adding weights at *H* increases the pressure which the valve *G* will maintain in the compartment *E* and consequently in the heating supply system. Transferring weights to *I* will obviously reverse the effect and decrease the pressure of the steam delivered to the heating system. In other words, the valve may always be adjusted to comply exactly with the pressure demanded by the heating system and any variations that may occur. The special construction of the piston *G* is very important as it secures steam sealing against air leakage for all positions of the valve. Steam pressures in chamber *E* reach the annular space through passages cut in the bottom of the valve. Snap ring packing at *S* minimizes all external leakage; whatever may take place accumulates in the compartment *Q* and escapes to the outside of the building through a vent pipe connected at *U*.

There may be frequent occasion to disconnect the turbine from the heating system and to operate the unit independently of the bleeder valve. This may occur in summer months when there is no demand for an exhaust steam supply. The valve may be lifted entirely out of the zone of action by turning the hand wheel *H'*. When the hand wheel is at its lowest position the valve becomes automatic and may assume any position in its travel which is determined by the balance of the steam pressure in space *E* and the valve weights.

In some installations it may be desirable to bleed all the steam from the turbine for extended periods. If the turbine is fairly well loaded, as it would probably be under these circumstances, it would prove more economical to have the steam pass through the entire turbine, providing none escapes to the atmosphere. This would be accomplished by an arrangement of piping such that the condenser could be cut out and the entire exhaust from the turbine directed into the heating system. This scheme may be followed out in the power house lay-out, Fig. 15.

It is far more essential that there be no interruptions of the pressure on the electric system than is the case in the supply of heat. Should the lights or motors stop there will invariably be some more or less serious complaint made of the service, while a short cessation of heat supply will more than likely be condoned. Moreover, there is natural storage capacity in the heating mains, radiators and the rooms themselves. But the instant the line

pressure fails in the electric system, the light and power cease, unless there is a storage battery floating on the line, now rarely installed and used. In view of these circumstances, it is possible to attach a special device to the turbine, which at times of brief heavy peaks in the electric load will automatically disconnect the turbine from the heating system allowing it to operate strictly condensing and thereby develop its maximum power.

The rotor of this bleeder turbine is shown in a separate view, Fig. 9. The bearing surface for the cylinder diaphragm packing separating the intermediate and low pressure sections, is in full view, and the counter-balancing dummies are shown at the left.

Several central stations have already availed themselves of this type of unit. One example is given in Fig. 10, which shows the engine room of the Kokomo Public Utilities Company, Kokomo,

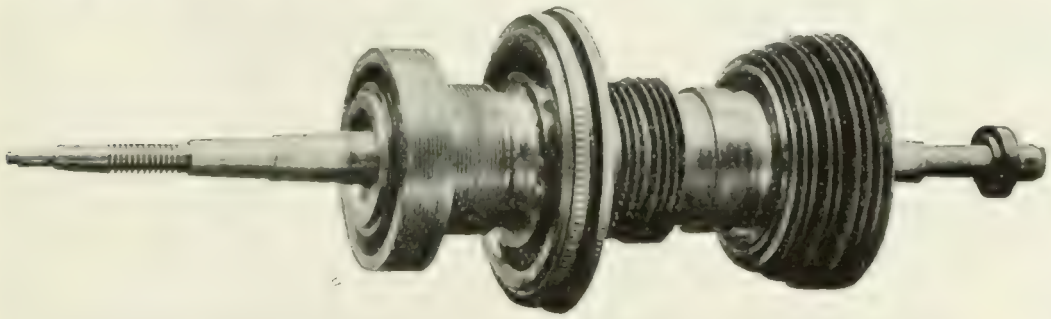


FIG. 9—ROTOR FOR AUTOMATIC BLEEDER TURBINE OF 1 000 KW CAPACITY

Indiana, in which a 1 000 kilowatt automatic bleeder turbine appears in the foreground.

CHARACTERISTICS OF STEAM-ELECTRIC UNITS

Non-condensing turbines have been greatly improved in construction, so that for moderate and large sizes, they may be properly classed as a close competitor of the steam engine. Typical water rates of a 1 to 3 ratio compound Corliss engine of 1 000 kilowatts capacity are given in Fig. 11, the conditions of operation being 150 lbs. gauge, dry and saturated, inlet pressure, with back pressures of 2 lbs. absolute and 1.5, 5.5 and 10.5 lbs. gauge respectively. It will be appreciated that the condensing water rate of the reciprocating engine is by no means excellent, owing to the fact that it has non-condensing cylinder ratios, and moreover, it was not deemed necessary to maintain a high vacuum. In this same diagram is also presented for comparison the economy of a 1 000 kilowatt standard condensing turbine operating under 150 lbs. gauge initial pressure dry steam and 28 inch vacuum.

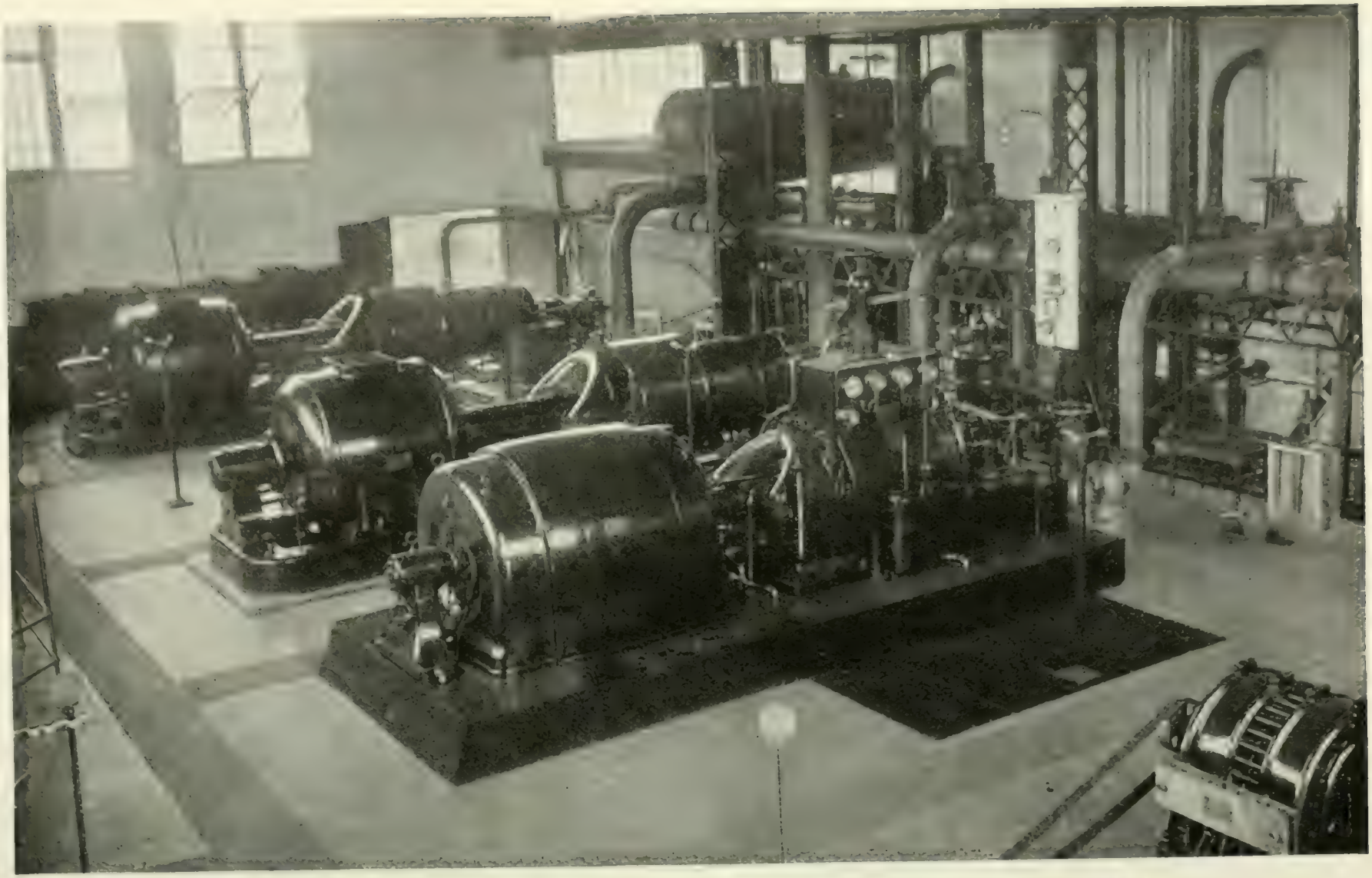


FIG. 10—ENGINE ROOM OF THE KOKOMO PUBLIC UTILITIES COMPANY, KOKOMO, INDIANA
1 000 kw automatic bleeder turbine in foreground

Regarding the comparative operation of the automatic bleeder and the turbine with the intermediate stage tap, it will be found that in addition to providing a large atmospheric steam supply, both the efficiency and power is greater than that of a turbine bleeding steam from the intermediate stage. An appreciation of this feature will be had in reviewing one of the characteristics; viz., direct variation of stage pressures with load, which applies to all makes of turbines except the Curtis first stage inlet where the full boiler pressure is utilized at all loads due to variable nozzle control.

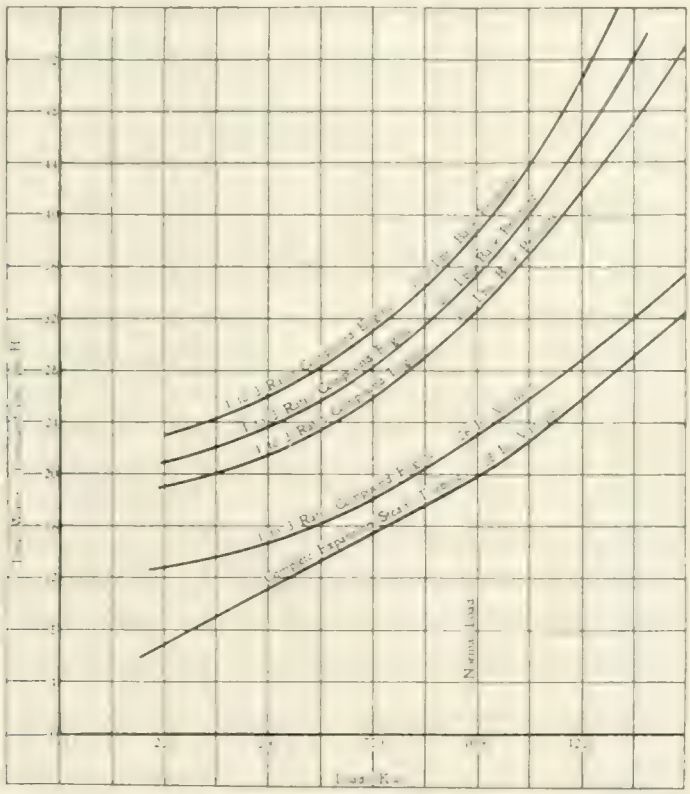


FIG. 11—TOTAL STEAM CONSUMPTION OF COMPOUND ENGINES AND TURBINES—1 000 KW UNITS

Taking dry saturated steam at 150 lbs. pressure under average operating conditions.

However, beyond the first stage, the Curtis turbine is affected in exactly the same manner as in other types, and therefore, suffers corresponding losses from bleeding at the intermediate stage, excluding of course any design built especially for bleeding operation. High pressure nozzle control has admittedly the advantage of greater bleeder capacity than the by-pass overload system taking steam from the intermediate stage, but the quantity of steam heat which may be furnished, is practically identical with the new Parsons bleeder turbine of equal power.

In any arrangement bleeding from the intermediate stage inlet, the possible work to be obtained in this stage is lost. The distribution of work throughout a turbine is divided roughly as two-tenths in the high pressure, three-tenths in the intermediate, and five-tenths in the low pressure section. This shows the significance of expanding the steam through the intermediate section before utilizing it in a heating system. While these proportions are more especially true of the Parsons turbine, the Curtis may vary some-

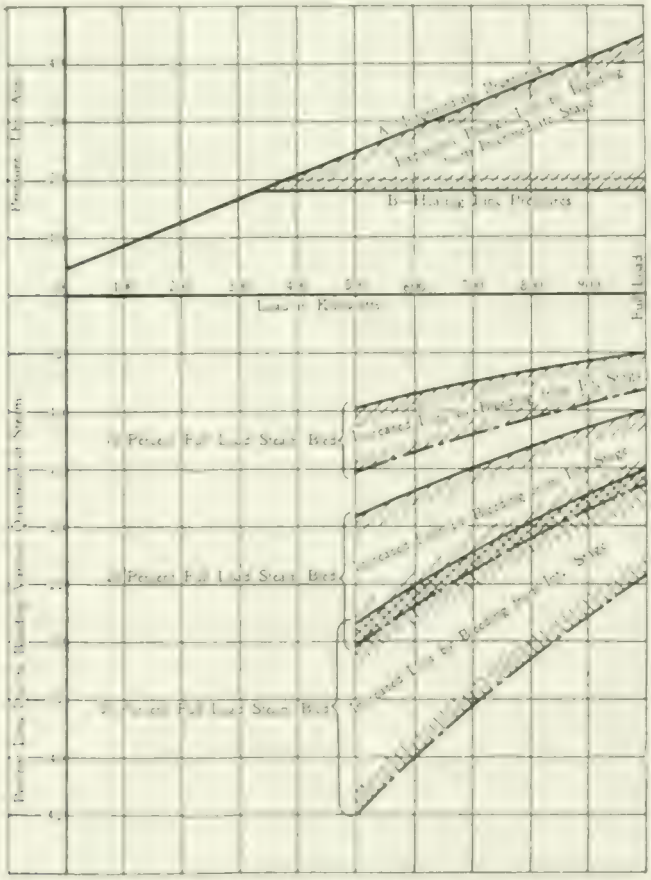


FIG. 12—ADVANTAGES OF LOW PRESSURE OVER INTERMEDIATE STAGE BLEEDING

what in the high and low pressure sections, but the intermediate work is approximately the same.

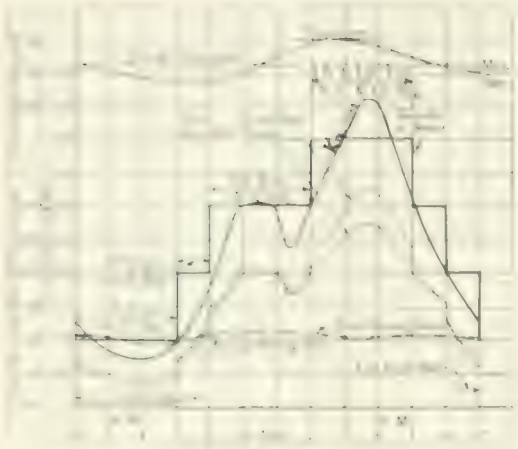
The advantage derived from bleeding at the entrance of the low pressure section, is shown graphically in Fig. 12, the upper portion of which indicates the pressure variation at the entrance of the intermediate section. With the bleeder connection at this point, considerable throttling losses occur, as will be appreciated from lines *A* and *B* representing the pressure at the latter section and the heating system respectively.

For every pound of steam bled, there will be a loss in expansive energy corresponding to the pressure drop from the intermediate section to the exhaust. If, however, the steam is expanded throughout this section before bleeding, the energy loss will be correspondingly reduced, the amount being equivalent to the additional work performed. The large drop in pressure occurring in the high pressure stage does not indicate that this section is doing a proportionate share of the work as the heat drop through high pressure ranges is far less than through the same range at lower pressure. The lower set of curves, Fig. 12, compare the loss in capacity which would be caused by the two bleeding systems for varying percentages of steam bled, assuming an equal amount of steam passing through each turbine. The quantity of heat per pound theoretically lost by cutting short the expansion at the intermediate pressures determined by the pressure-load line *A*, has been computed and expressed on a percentage basis for different amounts of steam bled. Values thus obtained, are shown by dotted lines, the solid lines representing losses that occur with the improved method of bleeding from the low pressure section. It is therefore, evident that the vertical distance between curves corresponding to equal bleeding demand, closely approximate the saving affected by a bleeding arrangement utilizing steam at low, rather than at intermediate pressure. In addition to being more economical, low pressure bleeding permits the operating of the heating system with the overload valve of the turbine open.*

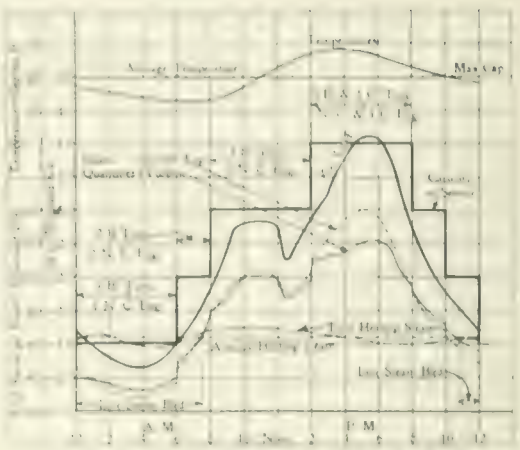
WORKING RESULTS—TOTAL CONSUMPTION OF MAIN UNITS

With the character of the steam and heating loads laid down, and the performances of the different units ascertained, the results for each successive month may be developed. In deriving the final curves, Fig. 14, an average curve sheet for each month has been prepared, and these appear serially in Fig. 13. To keep the related curves together, the average hourly temperatures were transferred from Fig. 3 and the steam required for heating during the day, from Fig. 4. The average hourly steam required is obtained from Fig. 4, and the variations occurring from hour to hour are interpolated from the previous data. The quasi-sinusoidal curves of the average day of the month

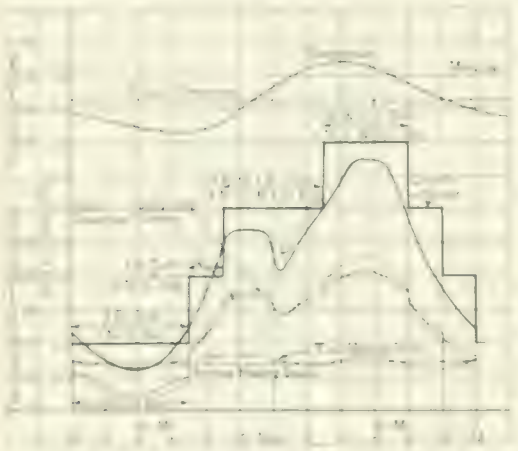
*For a discussion of the performance characteristics of automatic bleeder turbines, see "New Developments in Steam Turbine Engineering" by the author in the JOURNAL for April, 1912, p. 292.



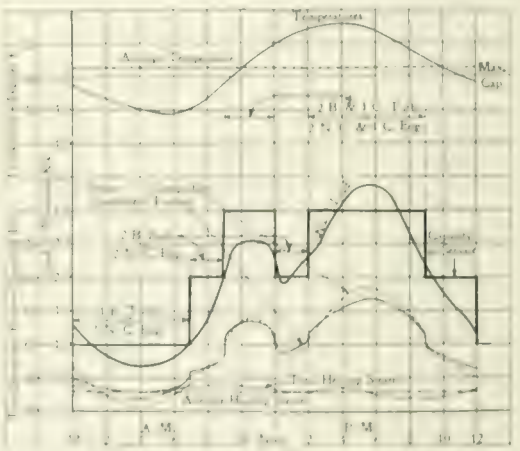
MEAN JANUARY DEMAND
Load Factor, 40.4 percent.
Total Kw-Hrs., 1 380 000.



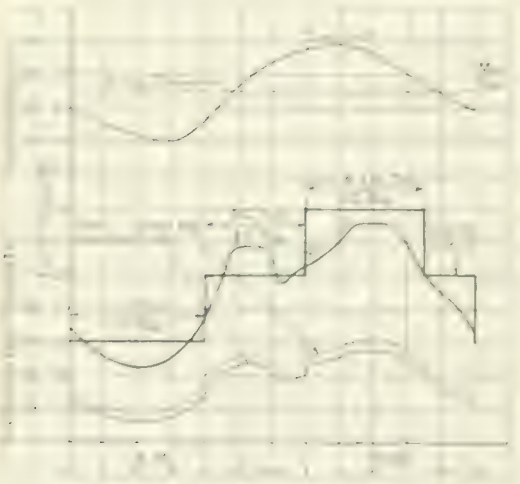
MEAN FEBRUARY DEMAND
Load Factor, 39.2 percent.
Total Kw-Hrs., 1 220 000.



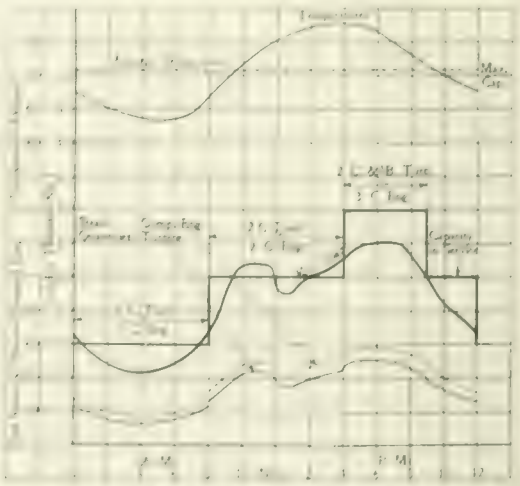
MEAN MARCH DEMAND
Load Factor, 36.8 percent.
Total Kw-Hrs., 1 250 000.



MEAN APRIL DEMAND
Load Factor, 33.8 percent.
Total Kw-Hrs., 1 120 000.



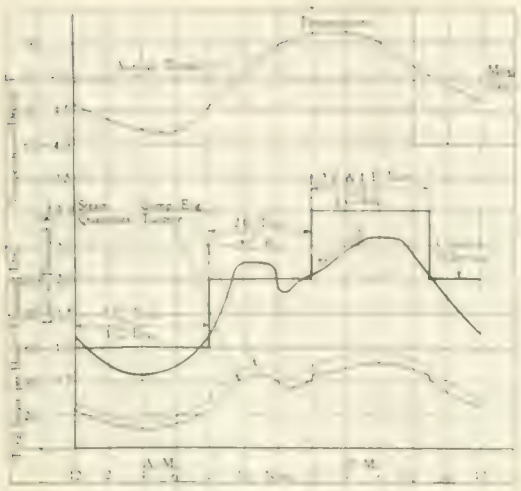
MEAN MAY DEMAND
Load Factor, 29.4 percent.
Total Kw-Hrs., 1 010 000.



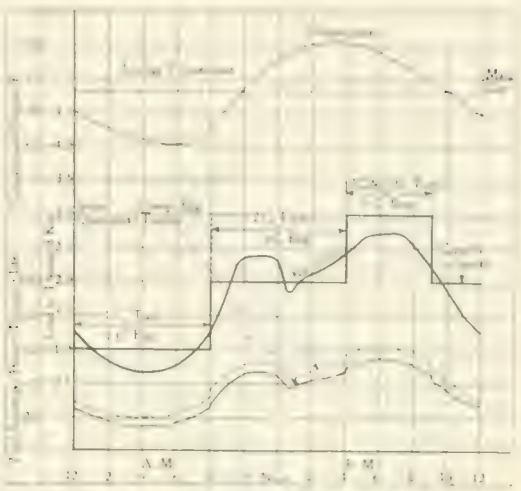
MEAN JUNE DEMAND
Load Factor, 28.4 percent.
Total Kw-Hrs., 942 000.

FIG. 13—REPRESENTATIVE DAILY GRAPHICAL LOGS

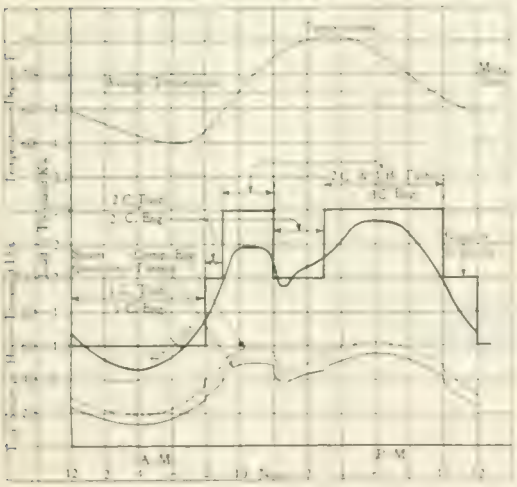
Load factor applied to Station Capacity and not the Maximum Demand



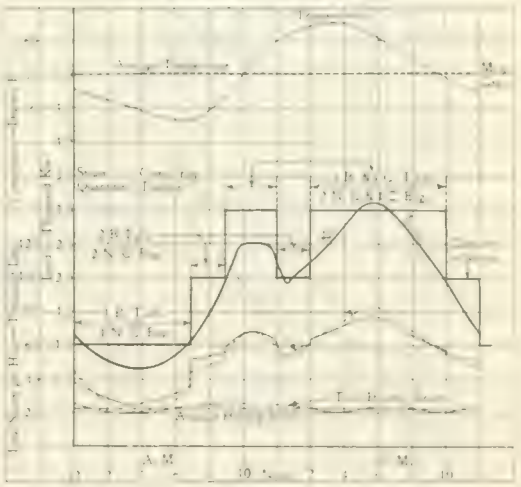
MEAN JULY DEMAND
Load Factor, 28.6 percent.
Total Kw-Hrs., 978 800.



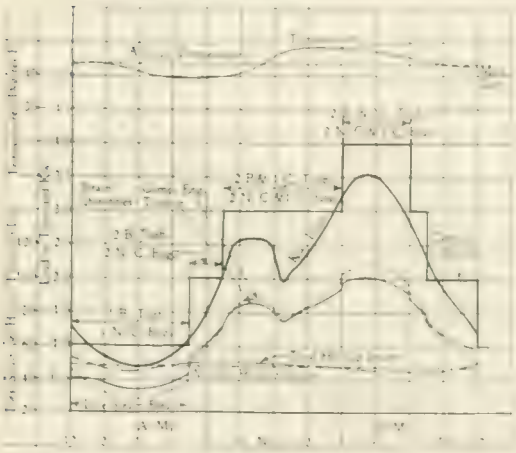
MEAN AUGUST DEMAND
Load Factor, 29 percent.
Total Kw-Hrs., 990 000.



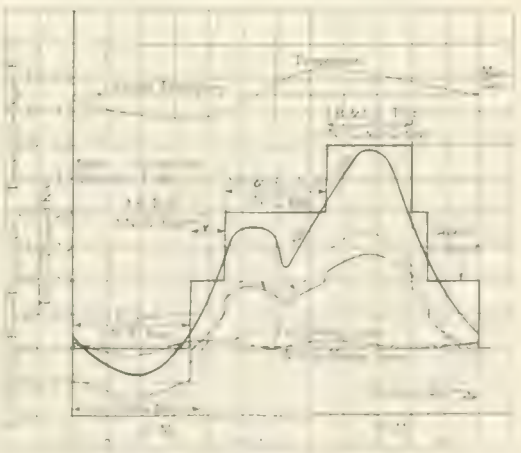
MEAN SEPTEMBER DEMAND
Load Factor, 30 percent.
Total Kw-Hrs., 995 000.



MEAN OCTOBER DEMAND
Load Factor, 31.8 percent.
Total Kw-Hrs., 1 090 000.



MEAN NOVEMBER DEMAND
Load Factor, 34.2 percent.
Total Kw-Hrs., 1 137 000.



MEAN DECEMBER DEMAND
Load Factor, 38 percent.
Total Kw-Hrs., 1 300 000.

FOR 5 000 KW STATION

The heaviest peak load usually occurs during the holiday season in December, but it must be remembered the monthly mean only is here employed.

have been made, in the case of the twelve conditions introduced, to correspond with the typical monthly difference throughout the year.

The total capacity of the units in service is shown by the stepped-lines. The units in operation, whether engine or turbine equipment, are scheduled on these average daily sheets, and this was planned so that no hasty cutting in or out of different types would be necessary if the load swung widely from the normal. Furthermore, there is ordinarily an appreciable surging of the load so that the curve of output is quite irregular instead of smooth as represented. The use of the smooth curve is permissible however, in order to facilitate the process of working out the final quantities,

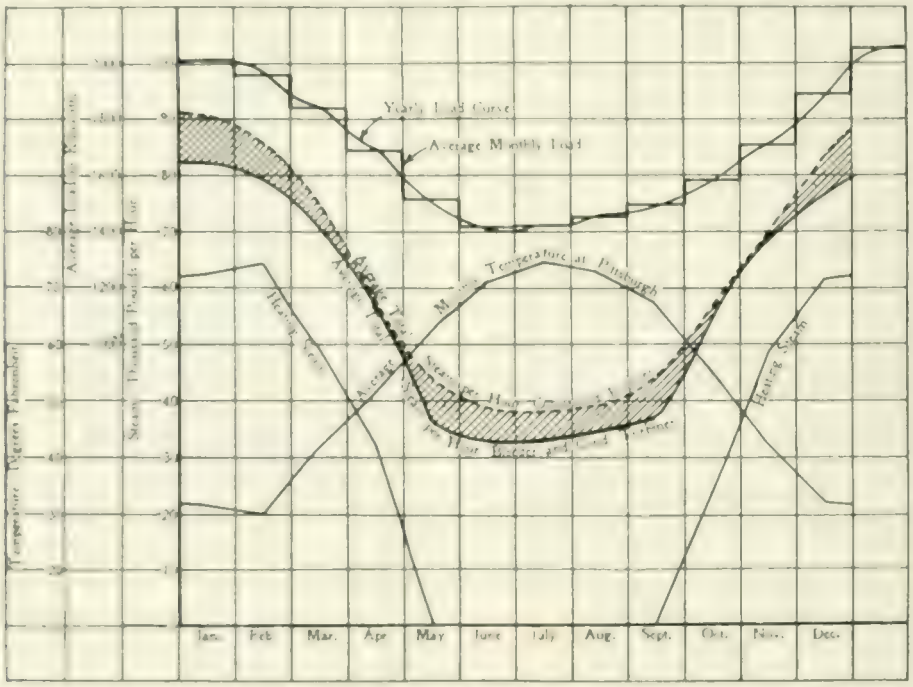


FIG. 14—SUMMARY CURVES

The crosshatched area indicates a saving, amounting to 10.6 per cent, to be effected by bleeder turbines.

so long as proper regard of the deviations is taken when determining a practice to follow in connecting or disconnecting the units from the bus-bars. This means that the non-condensing piston engines are used more than theoretically necessary with the attendant sacrifice in economy. Taking the loads and the steam demands and referring back to the original data, the various points on the final steam consumption curve were determined.

On the monthly curve sheets is shown the fact that for a few hours in the early morning the power load is so light that live steam must be bled to the heating main. This live steam is taken as part of the plant consumption, and is included in the curves in Fig. 14.

According to the curve in Fig. 4 there would be no demand

for heating steam when the outside temperature reached about 60 degrees, and since the average monthly temperatures of May and September are more than 60 degrees, no heating requirement is shown for these months. It is evident, however, that during a part of these months some steam would be required, and hence the value of the Total Steam for these two months has been increased slightly when transferred to Fig. 14, which presents graphically the fact that the automatic bleeder turbine plant follows the heating steam requirement curve much more closely than the compound engine plant, indicating about 10.6 percent less steam used per year by the bleeder turbine equipment than by the piston engine plant.

While the automatic bleeder turbine installation has not shown itself to develop very much better steam economy than the engine plant in the particular case worked out, it is, nevertheless, considerably better when the other operating aspects are taken into consideration. It is to be noted in connection with the basic data used that the engine economies are those which have been wrought out through many years of development, and that maintaining them involves attention on the part of the operating force greatly in excess of that required by the turbine. On the other hand, the turbine economies are very conservative since this type of machine is in the early part of its development period. When viewed from the various angles, it is definitely evident that the turbine of the special design described would serve the central station interests best. By adjusting itself automatically to all changes in conditions, these results show that this type of plant becomes inherently of higher economy than any other plan which has been devised.

OTHER ECONOMICAL FACTORS

The students of power plant engineering have come to understand that the items of engine room cost may be reduced with turbine machinery over that of piston engine operation, providing the size of the plant is at least 2 000 to 3 000 kilowatts. Labor, maintenance, oil and investment should obviously be less, and moreover with the elimination of the oil in the exhaust, the pipe lines and radiators should require less attention.

THE POWER HOUSE LAYOUT

As exemplified in Fig. 15, some novel and advantageous features may be introduced in a plant of this kind, all exciters may be direct coupled to the generator shaft. An auxiliary exciter for emer-

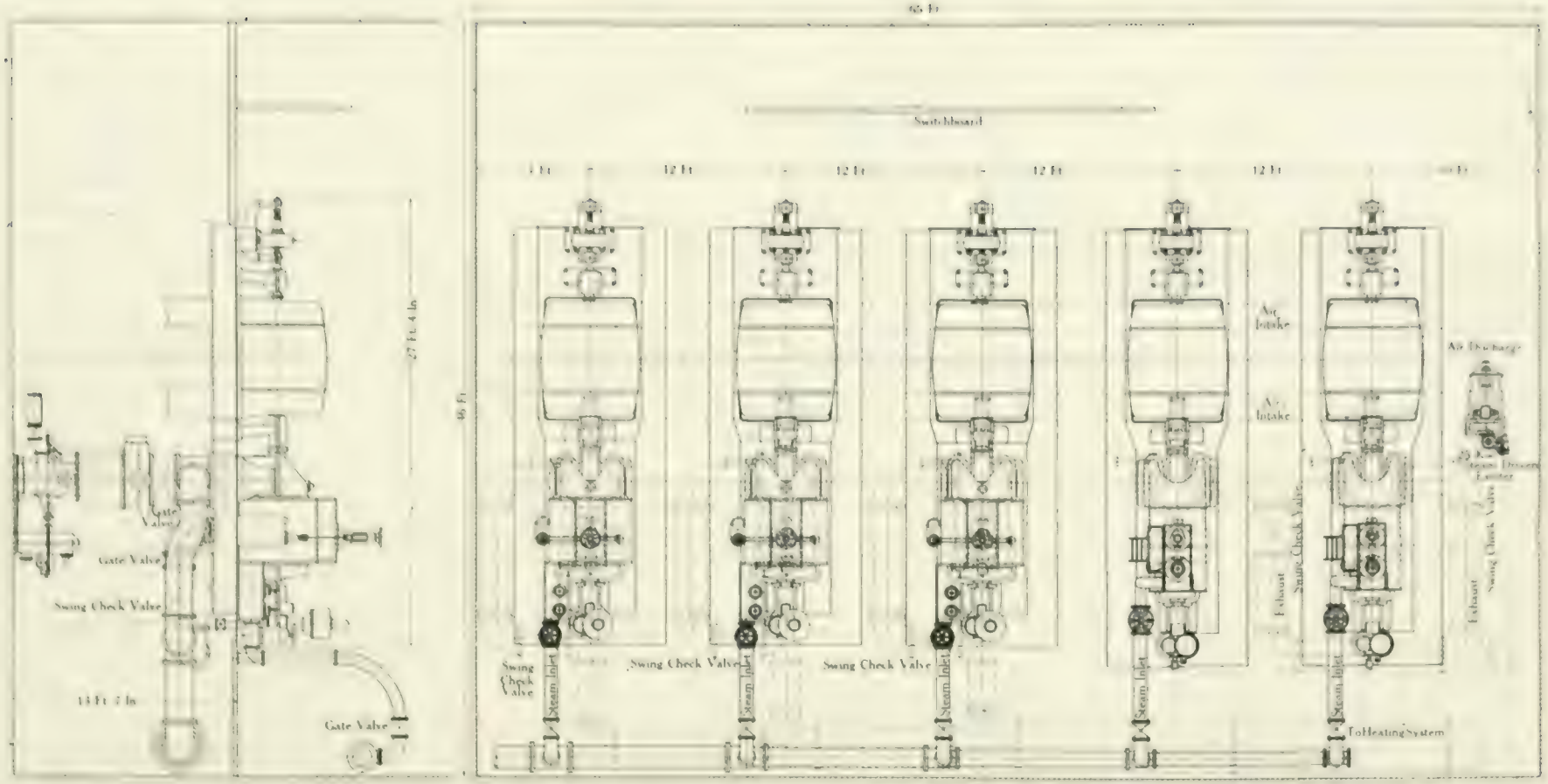


FIG 15—LAYOUT OF 5 000 KW STATION USING THREE BLEEDER AND TWO CONDENSING STEAM TURBINES OF 1 000 KW CAPACITY EACH
Bleeder Turbines to the left and in elevation.

gency may prove a wise precaution. In no case, then, need the drive of the auxiliary machinery be selected with a view of a precise heat balance. It should be chosen entirely on the ground of greater reliability and convenience. Such steam-driven auxiliaries as may be provided would be connected into a common exhaust leading to the bleeder main in the power house. From this bleeder main a branch would supply the exhaust for the feed water heater and may in turn be regulated by a suitable thermostatic valve.

It will be seen that the extra heating main in the power house adds no complication. In future power house plans, it will be desirable to immediately have lesigns so arranged that this new bleeder proposition may at any time be introduced without any material alteration. As a public utility, district heating may grow rapidly in popularity and the far-sighted managements will no doubt prepare themselves for this development. When coal prices rise, this state of affairs will be hastened. The automatic bleeder turbine unit costs but approximately 7½ percent more than the standard condensing machine, and it may, therefore, be the better part of wisdom in many cases to install such a type of machine, notwithstanding the fact that no heating system may exist at present or be immediately projected. Moreover, with a unit of this construction, its properties should possess no small value as it should suffer least from obsolescence.

QUALIFYING CONDITIONS

Apparently no set recommendations may be made unless local conditions are absolutely known. For instance, if natural gas or low priced coal of good quality exist in the vicinity, a combined plant may not be considered favorably. However, such sections are few, and with coal prices generally on the advance, drawbacks of delivery of fuel, unsatisfactory burning, the growth in the idea of steam heating as a modern convenience, enactment of rigid smoke ordinances and the like, may stimulate the steam heating industry, although in the first mentioned cases, it may be considerably retarded. The entire paper deals with exhaust steam heating. The hot water system has its advantages in some sections, and it is probable even in that event that the same type of station as herein discussed should be installed, except that a closed heater should also be introduced and be connected with the bleeder nozzle of the special turbine described.

SOME NOTES ON LOADING LARGE ALTERNATING-CURRENT GENERATORS

L. D. NEWBURY

THE obvious impossibility of loading large alternating-current generators at the manufacturers' works under actual energy load has led to the development of various methods of approximating such actual load conditions. The methods in common use are:—

1—Separate open-circuit and short-circuit tests;

2—Zero power-factor tests; and

3—The so-called direct-current open-delta test in which the field winding is excited to generate the full-load core losses (as nearly as these can be approximated on open-circuit) and the armature winding is connected in delta with one corner open through which direct-current is introduced.

OPEN-CIRCUIT AND SHORT-CIRCUIT METHOD

In the open-circuit and short-circuit tests, the generator is first tested with the armature winding on open-circuit and the field winding excited usually to give a higher armature voltage and core loss than under normal load conditions to compensate for the absence of the armature winding loss. Obviously, the temperature measurement of the armature winding is of little value. To obtain an adequate measure of the temperature rise of this part, the armature winding is short-circuited through ammeters and the field excited sufficiently to circulate more than normal full load current. Under these conditions the core and field winding losses are much less than under normal load conditions and, consequently, the temperature measurements on these parts are of little value. The open-circuit test, therefore, is of value to determine the core and field winding temperature and the short-circuit test to determine the armature winding temperature.

The open-circuit and short-circuit tests have the advantage of simplicity in operation and in apparatus required. No testing equipment is required other than a small driving motor and the measuring instruments. For this reason it is often the only possible method that can be carried out under factory conditions. The main disadvantage of the method is the uncertainty in the proper interpretation of the results. This uncertainty arises from the fact that the core loss and armature winding loss are not present in the

same test, so that the combined effect of the two losses on the core and winding temperatures must be approximated from the separate test results. Experience has shown that in the large majority of machines the normal load core temperature will be lower than the open-circuit core temperature when the open-circuit voltage is approximately ten percent higher than normal, and that the normal load armature winding temperature will be lower than the short-circuit test results when the short-circuit current is approximately 25 percent higher than normal. This increase, however, varies with the amount of insulation on the winding, i.e., with the generated voltage—a smaller increase being required with the higher voltages.

But, unfortunately, experience has also shown that, in occasional machines, the open and short-circuit results form no guide whatever to the actual load results. For example:—

With a number of water wheel driven, 3 000 k.v.a., 2 200 volt, 60 cycle 225 r.p.m. generators tested six years ago, the open-circuit test showed a core temperature rise of 32 degrees and the short-circuit test showed an armature winding temperature rise of 30 degrees. The temperature rise in the core on short-circuit test was also 30 degrees. These results were all well within the guarantees and the design of the generators was not questioned. After shipment, tests on normal load developed the fact that the core temperature rise was not below 32 degrees but above 50 degrees. On the other hand, the temperature rise of the armature winding was well below the results on short-circuit test, being 19 degrees.

The high core temperature was reduced by correcting faulty air circulation, and a repetition of the compromise and actual load tests gave the following results:—

Open-circuit test (15% over-excitation)	Armature core	27 degrees
	Armature winding	17 "
	Field winding	28 "
Short-circuit test (normal current)	Armature core	15 "
	Armature winding	15 "
	Field winding	6 "
Actual load (average of 5 tests); 100 percent power-factor; normal current and voltage	Armature core	30 "
	Armature winding	15 "
	Field winding	23 "

With proper air circulation, there is substantial agreement between the results of the compromise and actual load tests. Comparison of the open-circuit and short-circuit tests before and after changing the ventilation shows very little change in core tempera-

ture on open-circuit, but shows a marked change on short-circuit. This and subsequent experiences have shown that a high core temperature rise on short-circuit test, even though below the guarantee, should be questioned as indicating faulty core ventilation.

A minor disadvantage of the short-circuit and open-circuit method of test is the inability to adequately test the field winding for temperature and exciting voltage margin. The field current used in the open-circuit test is approximately equal to the field current required at full load and 100 percent power-factor. To test with a field current even approaching that required for the maximum load and low power-factor, for which the generator is designed, would result in a prohibitive core loss and temperature. With this method of testing, the guarantees involving the field winding must be checked by calculation from the relatively low field current used in the test.

These limitations, inherent in the open circuit and short-circuit method of testing, have led to the practical abandonment of this method, except in those cases where, from lack of equipment, a better test cannot be made. When the method is used, care and extended experience is necessary in the interpretation of the results.

ZERO POWER-FACTOR METHOD

The zero power-factor method of loading has almost entirely replaced the open-circuit and short-circuit method. With this method the generator under test is operated in parallel with a generator of the same voltage and frequency, and of at least equal current capacity. The generator under test is over-excited and the generator in parallel with it under-excited until the desired armature current flows. The generator under test, therefore, is operating under normal voltage, normal current, and a field current whose value approximates the maximum which will ever be required under operating conditions. The test is, therefore, made under more severe conditions than actual full load at any operating power-factor. This is a desirable condition from the standpoint of both manufacturer and purchaser. Although possibly not generally appreciated, it is none the less true, that the best interests of the manufacturer demand tests which will be more severe rather than less severe than actual operating conditions. The responsible manufacturer is more interested in preventing the shipment of defective apparatus than the purchaser, since the correction of defects

is much more expensive after shipment than before, not to mention the loss in good will that the shipment of defective apparatus is apt to entail.

The one limitation in the application of the zero power-factor method of loading is the necessity for testing equipment equal in k.v.a. capacity to the generator under test. When there are two duplicate generators being built, this limitation obviously does not apply since one generator can be tested in parallel with the other. This duplicate generator will not always be available and, in some cases, even when it is, the expense for a duplicate test rig may be prohibitive. This is generally the case with large vertical generators where the thrust bearing is supplied as part of the water wheel. Under such circumstances, to employ this method of test requires expensive testing equipment covering a range in voltage, frequency, phase and k.v.a., equivalent to that of the manufacturers' output. To meet these conditions, one of the large electric manufacturing companies has installed a testing generator of 6 000 k.v.a. capacity, and the same capacity in transformers. Either single large generators or a number of smaller units are tested simultaneously at zero power-factor from this large testing generator. Numerous comparative tests made at zero power-factor and under actual load conditions show the substantial agreement between the zero power-factor and actual loading.

DIRECT-CURRENT OPEN-DELTA METHOD

In some cases where the equipment for zero power-factor tests is not available, for example in the case of a 40 or 50 cycle generator, the direct-current open-delta method may often be used in the case of three-phase generators. This method of loading, while not approximating actual load conditions as closely as the zero power-factor method, does approach such conditions much more closely than the open-circuit and short-circuit method. The armature winding of the generator under test is connected in delta, if not originally so connected, one corner of the delta is opened, and direct-current equal to normal current is introduced at this point and circulated through the armature winding. The core loss is obtained by exciting the generator as for the open-circuit test, but since the armature winding loss is present the excitation need be no greater than for normal voltage. The test conditions are the same as actual load conditions, except for the lower field winding loss and for

whatever difference results from the use of direct-current instead of alternating-current.

With direct-current in the armature winding, a stationary field is set up which will produce eddy currents in any solid portions of the rotating part. This direct-current field has a pole for each phase of each pole or three times the number of poles of the generator. With chorded armature windings, the value of this field is reduced until, with a three-phase winding having a throw equal to two-thirds of the pitch, this direct-current field disappears. With alternating-current in the armature winding, the field due to the armature current rotates synchronously with the rotor so that these losses are not present. These losses, however, are negligible with rotors having laminated poles. This method, therefore, is practically limited to generators having such rotors, and, in general, rotors without any considerable mass of solid metal unless the armature winding is considerably chorded.

The correct field current to use with this method of loading is very little more than the field current to give normal voltage on open circuit and no appreciable error is introduced by the use of a value of field current corresponding to open-circuit normal voltage. Obviously, the excitation should be such as to duplicate full-load core loss as nearly as this can be duplicated without alternating-current in the armature winding. This condition will be attained when the excitation is sufficient to produce the flux required for an induced voltage giving normal terminal voltage and normal armature current. The flux is equal to the flux required to produce an open-circuit voltage representing the vector sum of terminal voltage, the voltage drop due to armature resistance, and the voltage drop due to self-induction of that part of the armature winding outside of the core. The larger field current actually required by load conditions (accounted for mainly by armature demagnetization) is neutralized by the armature load current and does not result in increased armature flux. That this value of field current is substantially correct is shown by numerous cases where the results of this method of loading have been compared with results from the zero power-factor method and from actual energy load.

COMPARISON OF RESULTS

An interesting case, in which such comparison was possible, was the test of a 12 500 k.v.a., 6 600 volt, 300 r.p.m., 50 cycle vertical water wheel generator. With an armature current of 877

amperes, corresponding to 10 000 k.v.a. at 6 600 volts, and with a field current of 281 amperes on zero power-factor, the temperature rises were:—

Armature core	35.5	degrees
Armature winding	35	"
Field winding	37.5	"

With the same armature current, using direct current, and with a terminal voltage of 6 700 (requiring 170 field amperes), the temperature rises were:—

Armature core	36	degrees
Armature winding	29.5	"
Field winding	17	"

The field excitation was slightly above that required for open-circuit normal voltage, and the core temperature was slightly above that obtained on the zero power-factor test. It will be noted that the armature winding temperature was somewhat below the rise with zero power-factor, which should be expected. The field winding temperature is, of course, considerably below, but will be found practically in proportion to the reduced loss.

Another example showing the comparative results with the direct-current open-delta method and actual energy load, is afforded by the same 3 000 k.v.a. generators mentioned above in connection with the comparison between open and short-circuit method and actual load. After the difficulties with ventilation were corrected, tests were made using the direct-current open-delta method of loading in order to prove whether the change had actually corrected the difficulties. The results of these tests were as follows:—

Method of Loading and Load	Temperature Rises		
	Armature Core	Armature Winding	Field Winding
Direct current; full load; normal voltage.	27	14	19
Actual full load; normal voltage; 100 percent power-factor	30	15	23
Direct current; 15 percent over-voltage; 25 percent over-current	39	21	30
Actual load; 15 percent over-voltage; 25 percent over-current	30	24	34

Another case where comparative tests with actual load and with direct-current loading are available concerns some 5 000 k.v.a., 300 r.p.m., 6 000 volt, 50 cycle generators. The results are as follows:—

Method of Loading and Load	Temperature Rises		
	Armature Core	Armature Winding	Field Winding
Actual load: 100 percent power-factor	34	30	30
Direct-current loading	35	25	25
138 percent actual load	43	46	27
138 percent load, direct current	42	40	29

Again, with some 1 400 k.v.a., 2 300 volt, 200 r.p.m., 60 cycle generators, the following comparative results were obtained:—

Method of Loading and Load	Temperature Rises		
	Armature Core	Armature Winding	Field Winding
Direct-current loading	22	14	8
Zero power-factor loading	24.5	17	17

Of the three methods of loading discussed, there is no question but that the zero power-factor method more nearly approaches actual load conditions, and the results will be, if anything, unfavorable to the apparatus. This is particularly true of the field winding temperature, but this temperature can easily be reduced to the guaranteed condition in proportion to the losses. The direct-current open-delta method of loading gives results very closely approximating actual load conditions, but the results will, if anything, be favorable to the generator. The armature winding temperature will be slightly lower than under actual load conditions, and the field winding temperature will be considerably below the maximum operating conditions. Accurate correction can be made for the field winding temperature, but no satisfactory correction can be made for the armature winding temperature. The short-circuit and open-circuit method of loading gives satisfactory results with machines having satisfactory air circulation, but this method will not directly detect faulty design in this respect. The results will, however, indicate such defect indirectly, and the method may be used when neither of the other methods are feasible.

THE ENGINEERING BASIS OF PROGRESS

CHAS. F. SCOTT

The University of Cincinnati has organized a number of cooperative courses in which the student devotes a part of his time to practical work at frequent intervals. The courses in engineering now cover five years of eleven months with alternating periods of work in the University and of service in the factories and industries of the city. The following article was delivered as the commencement address before the graduating class of the University of Cincinnati, June, 1912.—[Ed.]:

WITHIN the past week I overheard two gentlemen discussing the business situation and the relation of the government to financial policies and the control of corporations. One of them declared, "No, you can't tell me that the business methods which have come from a thousand years of experience are wrong and need serious change." I was tempted to ask whether his grandfather might not have said, "No, you can't convince me that the stage coach, the evolution of a thousand years will be discarded for an engine on wheels." But the stage has gone, the horse car has disappeared and automobile manufacture has in a decade become one of our most important industries. And these but typify the changes which have taken place on every hand. I have lived in Pittsburgh, where the little forge in which Andrew Carnegie became interested fifty years ago has become the most gigantic corporation in the world. I have moved to New England where the poetry of Priscilla's spinning wheel has been lost in the hum of great textile mills. But I need not continue, for you are familar with many instances in which progress within your easy recollection exceeds that of a preceding century.

Are all these things independent, or are they somehow related, and can it be that they have directly or indirectly resulted from a single fundamental cause? A short time ago I examined with much interest a mechanical dictionary published in Paris about 1750. It was a large book and had many excellent engravings which showed machinery of various kinds for working wood and metal. There were lathes and large hammers and many ingenious devices which were the prototypes of present-day machine tools. In fact, so many familar things were shown that one began to wonder how much is really new in modern machinery. But there was one fundamental difference, the old machines and tools were all operated by hand power. They were designed before the days of James Watt. The little hand hammer of olden times has become a steam hammer of a thousand tons; the little lathe is now a great power lathe cutting great ribbons from the hardest steel; a man's arm no longer drives the tool but his hand directs the power of the

great engine. The engine on the ship replaces the galley slave, and the locomotive whistle sounded the death knell of the stage horse. Mechanical power has produced vast changes in every phase of life; there is scarcely a material that we use in our buildings, or our clothing or for food, that has not been acted upon by mechanical power in manufacture and in transportation. The development of mechanical power is no simple, ordinary thing—it is preëminently unique, it stands alone as the great physical event. Mr. Morrison entitled his book describing it as "The New Epoch," the only one since civilization began. The steam engine supplied the power which underlay the progress of the nineteenth century.

The applications of electricity have increased marvelously, because electricity is a useful means of distributing and using mechanical power. It simply enlarges the field in which the engine has produced such overwhelming results. At the Centennial Exposition, thirty-six years ago, two of the remarkable exhibits were a great engine of 1 000 horse-power and a dynamo which operated one arc lamp. Steam turbines, developed to operate dynamos, are now made of 30 000 horse-power capacity, and larger ones will soon follow. By the electric method power can be carried many miles and used for lighting streets and houses, for running railway trains and street cars, for operating elevators and printing presses, mills and factories, sewing machines and ventilating fans, for cooking, and a thousand heating devices, and it can ozonize and purify the air we breathe and the water we drink. Power has transformed the methods of transportation and manufacture in the past; in the future, in electric form, it is likely to effect corresponding transformations in domestic life.

One of the results of the use of mechanical power is that things can be and are conducted on a larger scale. The locomotive has made our country a unit, smaller in size as measured by time and ease of travel than were the original colonies. A gentleman told me a few days ago that he had come from China by regular routes of travel in twenty days—doubtless more quickly and far more comfortably than was a journey from Maine to Carolina sixty years ago. A continent, or in fact the whole world, becomes a compact unit. Wheat from Alberta or Argentina reaches London about as cheaply as it used to come from the fields of England. In manufacture the engine created the large mill and factory, enabling men to work effectively in large groups. Electricity has wonderfully extended the possibilities of cooperative action. The

telegraph and telephone have perfected the transmission of intelligence, making possible political, commercial and social action on a vastly large scale, while electric transmission and distribution of power is bringing together into combined operation things that were diverse and unrelated. The operation of lighting systems, and street railways, and factories and sewing machines, and cooking stoves, all from a single water power or steam engine established a physical basis for the public service corporation. Modes of life have changed. Each family does not raise its own food and make its own clothes. We depend upon one another for the necessities of life. Isolation and individual independence have given way to intercourse and mutual dependence. The engine has laid the basis for a new kind of community life. To use large mechanical power and to develop large results in human activity men must now act together. In other words, the new mechanical or physical basis which the application of power has given to modern society supplies the means for a new way of living and establishes a new order of civilization.

To see how the human re-adjustment follows the new physical conditions we have only to examine some of the important problems of the present time:—

The Interstate Commerce Commission, with its enlarging influence and authority, has its basis in the original Constitution of the United States. Interstate commerce, however, as we now know it, hardly existed in the first three-quarters of a century of the country's history. It is the steam locomotive which has made modern interstate commerce with its present far-reaching problems.

The conservation of our water powers has been a foremost economic, legal and political question during the present administration. Why have our water powers—quiescent through all history—come to acute prominence so suddenly? It is because the electrical engineer has shown how to transmit the energy of the wasting water power and make it useful.

The relation of the government to the trusts is a growing problem. What has made the trusts? On what physical condition is their existence based? Practically every large organization is based upon manufacture and transportation. The extensive use of power makes possible economic production on a large scale, while modern travel and freight transportation enable men in different places to work together efficiently. The trust did not exist a century ago because it could not. These new economic conditions are

based upon the new engineering conditions and it is folly to attempt to maintain the economic principles and practices of a century ago. The producers of public necessities—of coal, or steel, or clothing, or bread—have not the freedom of individuals, but they have assumed obligations as public servants, whether they be termed companies or public service corporations or departments of the government. The statesman or reformer who attempts to meet the new conditions by the rules and traditions of the past, without recognizing the new order of things, will fail. It is the method, not of the traditional lawyer, but of the constructive engineer, which is needed to bring to society the full fruits of the economic advantages of the modern corporation.

The present social and industrial unrest is manifesting itself in acute form in the industrial strike. The present relations between labor and capital have been brought about in industry and transportation by the modern methods which in turn are based upon the application of power. Speaking broadly, the engineer has brought into modern industry new conditions for efficient production, and men have not as yet adjusted themselves in justice and efficiency to these new conditions.

The high cost of living, the increasing cost of food and of clothing are attracting general attention. Now the cost of production is reduced by modern manufacture and low freight rates. The physical factors in production are more efficient than ever before but we have not yet adjusted the human element, the human relations, the relations between labor and capital, and we have not secured an efficient means of distributing the wealth now produced.

Another of our present problems is the city. The census shows that our population is shifting from the country to the city. Now the city depends upon applied science and engineering for its physical basis, and it is because these things give life so much larger possibilities that men are drawn from the isolation of the country to the city. Community life has taken on a new form. The political and administrative methods of the past are inadequate. The old-time political appointee cannot be trusted to run a water works or a health department. In city life and city government the question is not so much whether science and engineering are adequate to meet modern needs but whether our methods of government and social administration are such as to utilize what science and engineering can provide.

Citizenship takes on a new phase. The individualism and independence of rural life must give way to common interest and interdependence in city life. Many of the industrial and economic mistakes of the present result from an attempt to apply old-time ideas regarding the freedom and liberty of the individual to the new conditions of community life and mutual dependence.

The new order of things which is a logical evolution from the application of science and the utilization of power during the nineteenth century has affected tremendously the function and methods of education. We all know of the great growth of colleges and universities, of their expansion; not only in scientific and engineering lines, but in a general breaking away from classic traditions to the wider fields of modern life. New types of education are appearing. Large corporations, such as stores, manufacturing companies and railroads, have instituted schools of their own for training men for their particular needs. The city corresponds in many ways to an industrial organization. It, too, needs trained men for the departments of its service, and in a larger sense it needs an intelligent, educated, trained citizenship so that its educational, commercial, manufacturing and social activities shall be wisely conducted. The true object of a city is to secure a larger measure of life for its citizens. The new training for citizenship must prepare for the special activities in city life and must above all impart the ideals of service, of efficient coöperation and of mutual dependence upon which successful city life must depend.

The University of Cincinnati has a world-wide reputation as an exponent of new ideas and new methods in education. It is a city university. It assumes new obligations between the university and the community. Its training is not abstract and isolated, but it is concrete and in contact with the city life, it is coöperative, combining theory and practice, study and work, knowledge and experience, it is a training for useful citizenship in the complex life of the modern city. This is not a freak or a fad in education, but it is a logical meeting of modern conditions. It is the logical outgrowth of a century's development in a new epoch.

You who graduate to-day are fortunate in the training you have received and still more fortunate if you have caught the modern spirit for which this university stands. I have told you that our present civilization is based upon the scientific applications of the past century and that the new epoch in which we live is the epoch of mechanical power. The engineer studies Nature's

laws and works in conformity with them. No invention, no machine can succeed which does not rest upon a basis of fact and of correct logical reasoning. The work of the engineer is based upon fidelity to Nature's physical laws. The present relations of the corporation to the public, and of the worker to the employer, are ill-adjusted because we do not, in our social and industrial relations, follow the method of the engineer. Selfishness instead of justice, expediency instead of right, tradition instead of new conditions, are too often foremost. Just as our modern ways of life are based upon the physical mechanism of the engineer so also must our social methods be the methods of the engineer. We must discover what are the fundamental principles of justice and right as well as of physics and mechanics. We must reason correctly and must aim at the same high efficiency in our human relations that is secured in the engine or the motor. If you are to be lawyers or business men or mayors, you should first of all be good engineers.

The engineer has put modern life upon a new basis by applying more effectively the materials and forces of nature to the uses of man. He has made it possible for a hundred men—or even a score—working together, to accomplish more than a thousand working alone. The constructive, progressive demand of the present is that human ability and human forces shall also be applied efficiently for the benefit of all. The moral principle upon which the new relations must rest is the principle of service, of benefiting others, of working for and not against, of peace and not war, of industrial harmony and not antagonism. The interdependence of modern life also finds the key to its problems in the idea of service, and we now see a new meaning in the saying of the Master two thousand years ago, that the greatest of all is the servant of all.

It was said a little while ago that Cincinnati, for promoting its own interests, once invested in the Southern Railway and that the city had benefited by the returns upon its investment. The tax payers of this city have likewise invested their money in this University. You who graduate are the security which the University gives in return to the city. You represent the bonds. Confidence has been placed in you. Do not betray that trust but give ample return in service to the city which has trained you. You are fortunate in the ideals of your Alma Mater. You have been trained in the cooperative school; take with you its spirit and live a cooperative life.

CHARACTERISTICS OF COMMUTATING POLE ROTARY CONVERTERS

J. L. McK. YARDLEY

COMMUTATION rather than armature heating had been the feature which limited the output of normally designed non-commutating pole rotary converters. That is, it had been easier to increase the output per pole without exceeding very conservative heating limits than to commutate the increased output without objectionable sparking or flashing at the commutator. The permissible speed was, therefore, a factor inherently involved in the design of rotary converters and depended upon the number of brush arms required to handle the current at the particular voltage and frequency employed. Slow speed machines of comparatively large proportions resulted. As the current and magnetic densities were low, high efficiencies were obtained despite the large amounts of material employed and no special ventilation of the armature was required in order to prevent objectionable increasing temperatures. The armatures almost invariably had an excess heating capacity which could not be utilized on account of limitations at the commutator. Obviously, advance in the art of building rotary converters was dependent upon the introduction of some feature which would place the heating and commutating limits more nearly on terms of equality. From the point of view of the economic utilization of material, therefore, the use of the commutating pole was justifiable.

Engineers who were responsible for the purchase of rotary converters were beginning to appreciate the importance of an increase in weight efficiency. They began to want the maximum performance in the least space and at a minimum cost, and in order to obtain this end were willing to abandon their ideas derived from the previous experience with non-commutating pole machines relative to current and magnetic densities, peripheral velocity, r.p.m., and pounds per kw. Interest in this subject was greatly stimulated by Messrs. B. G. Lamme and F. D. Newbury, through their paper on "Interpoles in Synchronous Converters" read before the American Institute of Electrical Engineers, November 11, 1910.* Tables and curves were given showing the limits which had been

*This appears in condensed form in the JOURNAL for Dec. 1910, p. 930.

attained in non-commutating pole converters and conservative predictions were made relative to the future of commutating pole converters. It will be interesting to point out what has been accomplished since that date. That there have been important developments is indicated by the rapidly expanding use of commutating pole rotary converters. The writer has been engaged in the design of a complete line of commutating pole rotary converters,

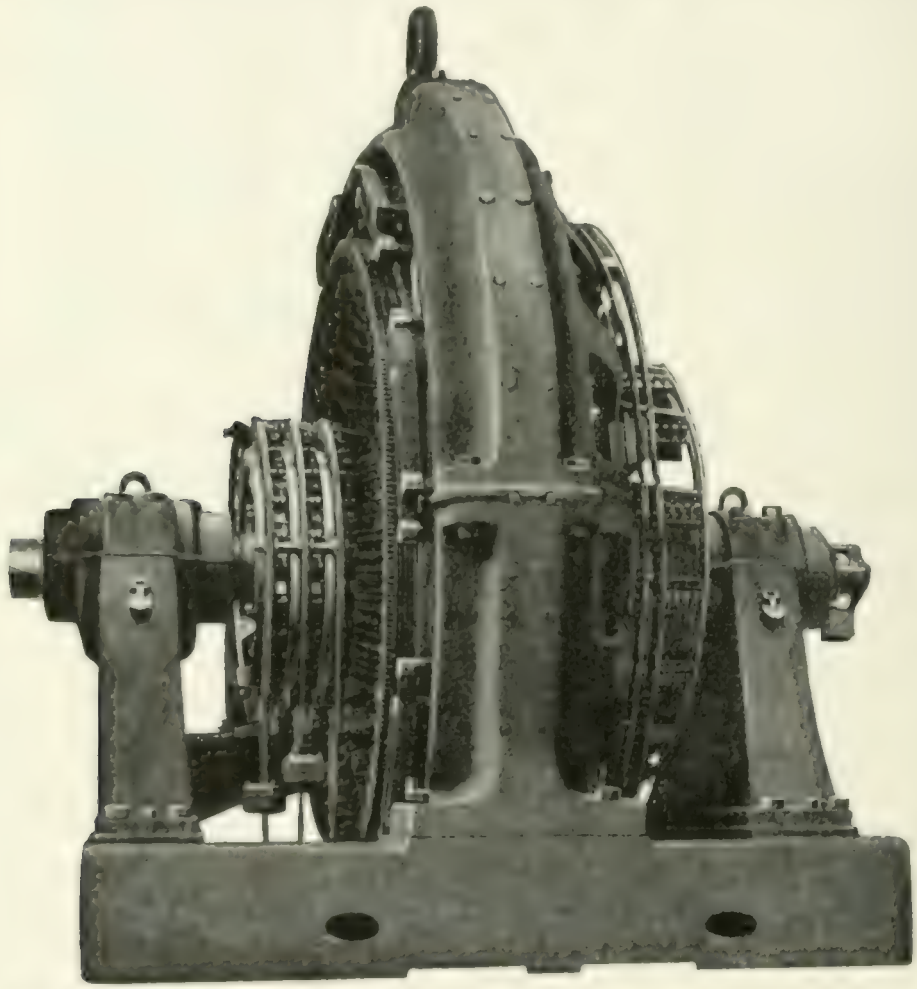


FIG. 1—3 000 K.W. 600 VOLT, 25 CYCLE, 187.5 R.P.M., COMMUTATING POLE ROTARY CONVERTER FOR RAILWAY SERVICE

and, to his knowledge, a total capacity of 81 500 kw has been contracted for within the past year from one manufacturing company, of which 39 000 kw are now building, and 15 500 kw are already shipped or in operation.

CHARACTERISTICS

The introduction of the commutating pole has greatly increased the permissible output per pole. By compensating for the armature reaction under the commutating pole to a great extent and by providing a properly shaped reversing field

for the armature conductors short-circuited by the brush (i.e., undergoing commutation), the previous limits as to "amperes per brush arm" have been considerably extended. By properly distributing the losses between copper and iron and by increasing the core ventilation, a construction has been arrived at which yields an efficiency as high or higher, and a temperature rise no greater, than that of the previous non-condensing pole converters, while the amount of material for a given output has been considerably reduced. Some characteristics of commutating pole converters which have been built and placed in service are given in Table I.

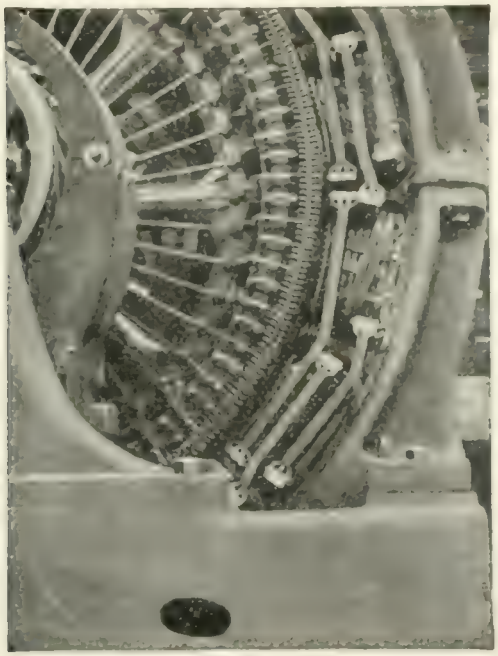


FIG. 2.—FIELD CONSTRUCTION OF 3000 KW ROTARY CONVERTER SHOWN IN FIG. 1

The first rotary converter referred to in Table I is illustrated in Fig. 1. It is started from the direct-current end and is operated in parallel with some 1500 kw and 3000 kw non-commutating pole converters. This converter has carried peak loads as high as 10500 kw. since installation last December. Its field construction is shown in Fig. 2. A laminated steel commutating pole is employed. The pole is enlarged at the base to give rigidity and to reduce the magnetic density and danger of saturation on overloads due to the

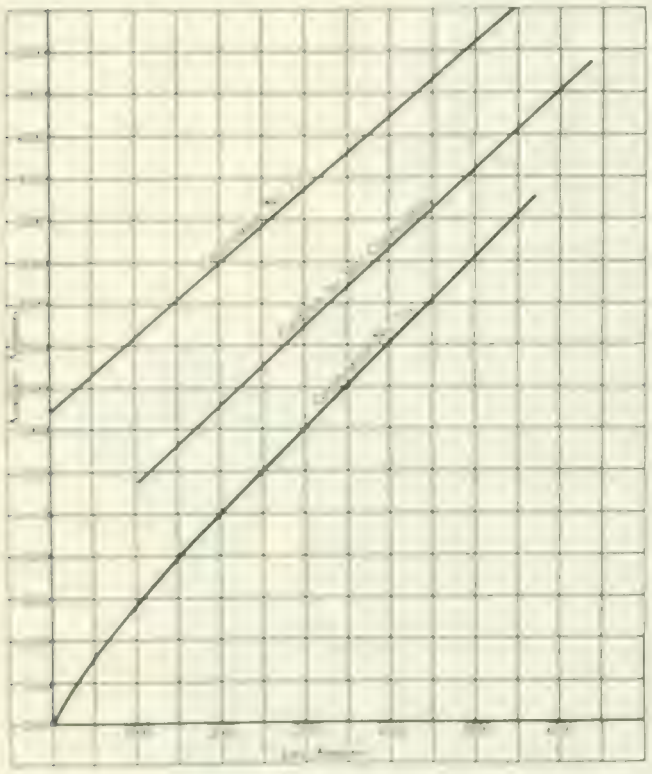
TABLE I—SOME CHARACTERISTICS OF COMMUTATING POLE ROTARY CONVERTERS NOW IN OPERATION

Normal Kw Rating.	Max. Momentary Kw Guaranteed.	Volts	Poles	R. P. M.	Cycles
3000	9000	600	16	187.5	25
2000	6000	650	12	250	25
2000	4000	600	8	375	25
1500	4500	650	8	375	25
1500	3000	600	6	500	25
500	1500	1200	4	750	25

reluctance of the joint when a cast iron frame is used. The winding consists of one turn per pole of several copper straps in parallel.

Commutation Tests—Commutating pole saturation curves corresponding to three different sets of adjustments of commutating

field amperes relative to line amperes, are shown in Fig. 3; and the readings of brush potential with relation to the commutator which correspond to different relations between line and commutating pole amperes are shown by the curves of Fig. 4. The abscissae of the curves of Fig. 3 give the direct current flowing in the armature of the converter, designated by "line amperes." The ordinates give the amperes flowing in the commutating pole winding, designated as "auxiliary amperes." It will be observed that these are straight line curves for the higher current values; in fact, if carried further for line current values corresponding to even 100 percent overload, they would still be straight, indicating that the fields are properly designed for operation safely below the saturation point or knee of the curve. The distance between the top and bottom curves indicates how far the commutating pole flux can be changed from the best value before objectionable sparking will be experienced. In other words, the distance between these lines is an indication of the commutating margin.



The abscissae in Fig. 4 give the brush width in the direction of commutator rotation, while the ordinates give the volts between brush and commutator taken at four equally spaced points along the brush width including the heel and toe of the brush. For the purpose of these tests the current in the commutating winding was

varied independently of the armature current and the voltage was read by means of a low reading voltmeter and two pointers, one held against the carbon of the brush near the commutator and the other held opposite it on the periphery of the commutator. The voltage drop readings obtained in this fashion are an indirect measure of the current density across the brush width, which, for the best results, obviously should be uniform.

The commutating pole winding is equipped with an inductive shunt, not shown in the illustrations but located at the bottom of the frame. By means of resistance in series, the current passing though this shunt is adjusted to the value which, according to the curves of Figs. 3 and 4, gives the best commutation. The construction of the main field windings is the same as for the non-commutating pole machines, except that the squirrel cage winding in the pole face (which is employed both as a damper and as a starting winding when the converter is operated self-starting from the alternating-current side) is not connected between poles. If the cage winding were connected between main poles it would form a short-circuit path of low resistance about the commutating pole tip and thus tend to damp out the variations of commutating pole flux due to changes in current in the commutating pole winding.

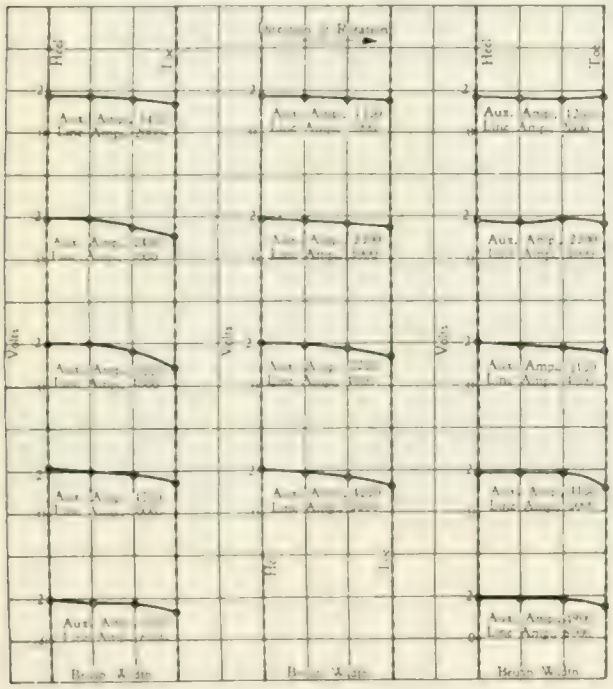


FIG. 4—BRUSH POTENTIAL CURVES OF 3 000 KW, 600 VOLT, 25 CYCLE, SIX-PHASE ROTARY CONVERTER

It is obviously important that the flux from the commutating pole be equal in time relation and proportional in amount, to the current. Hence the use of the laminated commutating pole. It has even been thought advisable by some designers to produce an over-compensating effect. By providing more turns on the commutating pole than necessary to truly compensate for armature reaction and produce a commutating field, and by shunting the excess amperes through an inductive shunt in which the ratio of in-

ductance to resistance is greater than in the commutating pole winding, the relation of flux to amperes may be changed in almost any desired degree. Such provision has so far been made on a number of converters, but experience has already shown that this additional feature is unnecessary. Where a shunt is unavoidable it should preferably be inductive, particularly if the load is fluctuating. In this connection it might possibly be expected that a frame of cast steel construction, owing to its greater magnetic retentivity, would cause the flux to lag so that noticeably poorer commutating

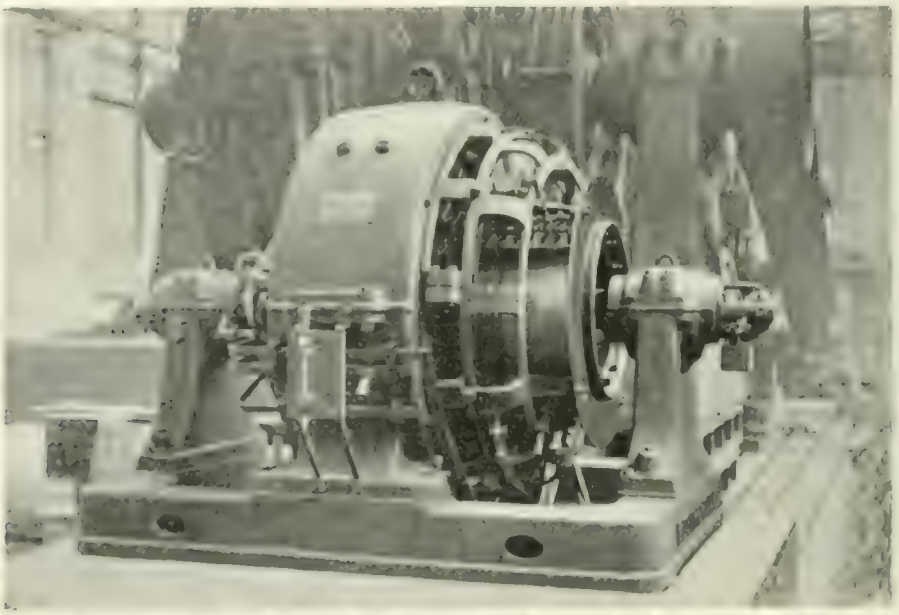


FIG. 5—500 KW, 25 CYCLE, 1 200 VOLT, 750 R.P.M. COMMUTATING POLE ROTARY CONVERTER FOR RAILWAY SERVICE

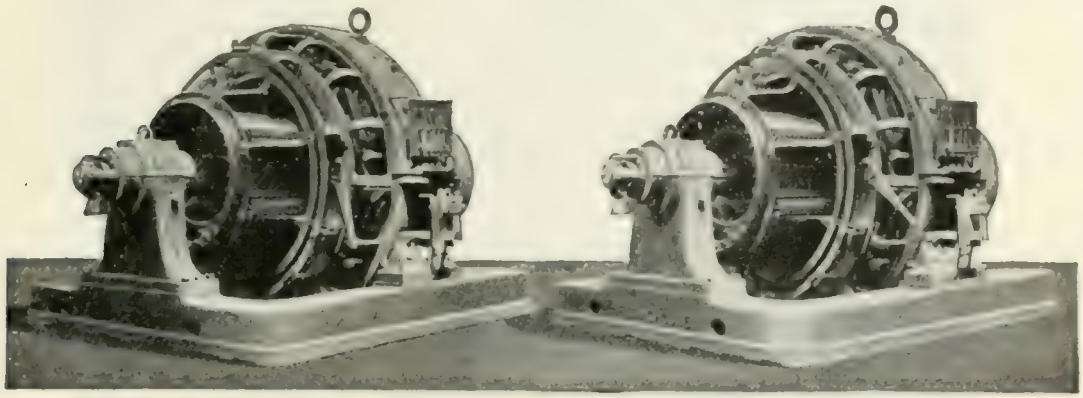
View taken on test floor, showing large synchronous booster rotary converter in background

characteristics would result than with cast iron construction. Such is not the case, however; and it has been found that, with the commutating winding designed so that no current need be shunted, a method of construction which employs laminated steel commutating poles with a cast steel frame enables the commutating pole flux to meet the commutating requirements so closely that heavy swinging overloads may be carried without excessive sparking.

A rotary converter of the latter type, having laminate steel commutating poles and cast steel frame is shown in Fig. 5. This is a 1 200 volt, 25 cycle, 500 kw, 750 r.p.m. converter which is capable of handling swinging loads up to 1 500 kw without a shunt on the commutating winding. It will be noted that this converter is provided with flash guards at the front and rear of the commutator, so that, in case of a flash-over under short-circuit condi-

tions, the arc is prevented from damaging the armature winding or commutator bushing and accordingly the converter may be immediately placed in service again without repair. In view of the high voltage on the commutator the addition of flash guards is advisable, inasmuch as it has been found in practice that any commutating machine of whatsoever design will flash over under short-circuit conditions unless protected by a sufficiently quick acting circuit breaker. In passing, it may be mentioned that the ordinary types of circuit breakers operated by increase of current are entirely too slow for this purpose.

A standard 2 000 kw, 600 volt, 375 r.p.m. commutating pole rotary converter for railway service, which has the ability to carry a 100 percent momentary overload without objectionable heating or sparking is shown in Figs. 6 and 7. This converter is started



FIGS. 6 AND 7—2 000 KW, 25 CYCLE, 600 VOLT, 375 R.P.M. COMMUTATING POLE ROTARY CONVERTER FOR RAILWAY SERVICE

In Fig. 6, the brush lifting lever is in, indicating that the brushes are on the commutator for running. In Fig. 7, the lever is out, indicating the brushes are off the commutator for starting.

by the direct application of alternating-current at reduced voltage to the collector rings. The introduction of the commutating pole in the interpolar space has so changed the magnetic conditions surrounding the conductors short-circuited by the brush that excessive sparking would result at starting if the direct current brushes were not raised. These brushes, with the exception of two of opposite polarity, are raised by a simple system of levers, the operating handle of which is seen at the side of the frame. These two pilot brushes are of reduced width, so as not to spark. They enable the field of the machine to build up and pull the armature into synchronism. The direct-current voltage is made to come up with the proper polarity by means of the field break-up and reversing switch

in the same manner as with non-commutating pole converters.* When the machine is in synchronism with the proper polarity, the starting switch is thrown to the running position and the brushes are all lowered to the commutator. Owing to an increased armature reactance, the starting voltage required for commutating pole converters is in general higher than for non-commutating pole converters; while, because of the reduced weight per kw and because the brushes are off the commutator, the k.v.a. input is greatly reduced. None of the rotary converters listed in Table I, requires more than 50 percent of its full load k.v.a. to start it from the alternating-current end.

A 1 500 kw rotary converter, such as the fifth listed in Table I, is illustrated in Figs. 8 and 9. This converter has no series field

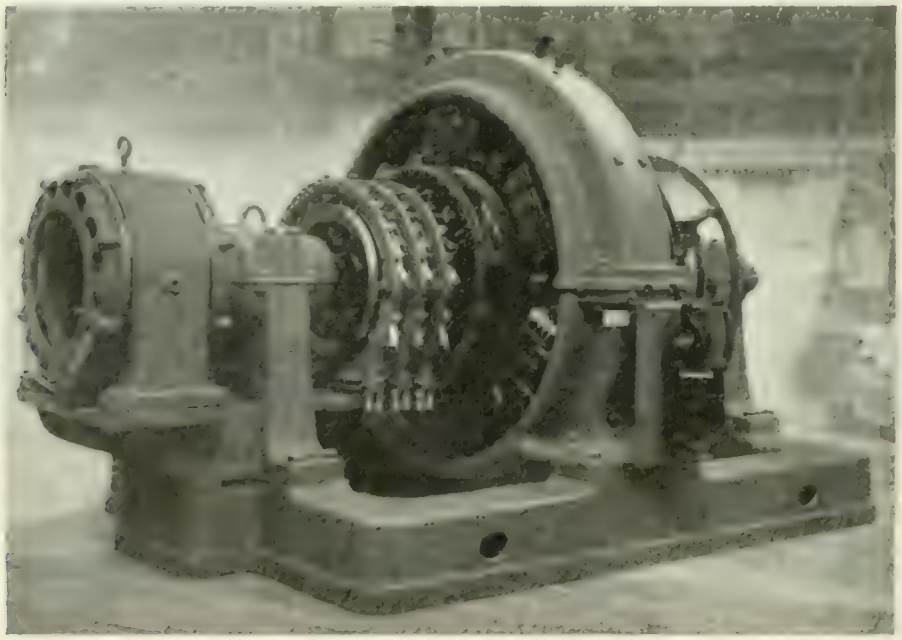


FIG. 8—1 500 KW 600 VOLT 25 CYCLE 500 R.P.M. COMMUTATING POLE ROTARY CONVERTER
View from alternating-current end

winding. The commutating field winding is arranged for three-wire operation. The converter is of the motor-started type and is synchronized by means of reactance coils; that is, when the motor has brought the converter to a speed in the neighborhood of synchronism and the voltage of the machine has built up due to self-excitation, the alternating-current circuit is closed with sufficient reactance connected in series with the alternating-current leads to prevent an excessive flow of current due to its not being

*For details of method of operating the field break-up and reversing switch see No. 470 of The Journal Question Box, Sept., 1910.

in synchronism. During the fraction of a minute required to pull into step, the armature "slips" a number of poles, and in so doing causes the flux in the commutating pole set up by the armature current to vary in amount and direction. To damp out this pulsating flux and prevent bad sparking at the moment of synchronizing, the two sections of the commutating winding are short-circuited by means of solenoid switches which are mounted on either side of the frame of the machine and are electrically interlocked with the switch of the starting motor so that they open when the starting motor circuit is opened.

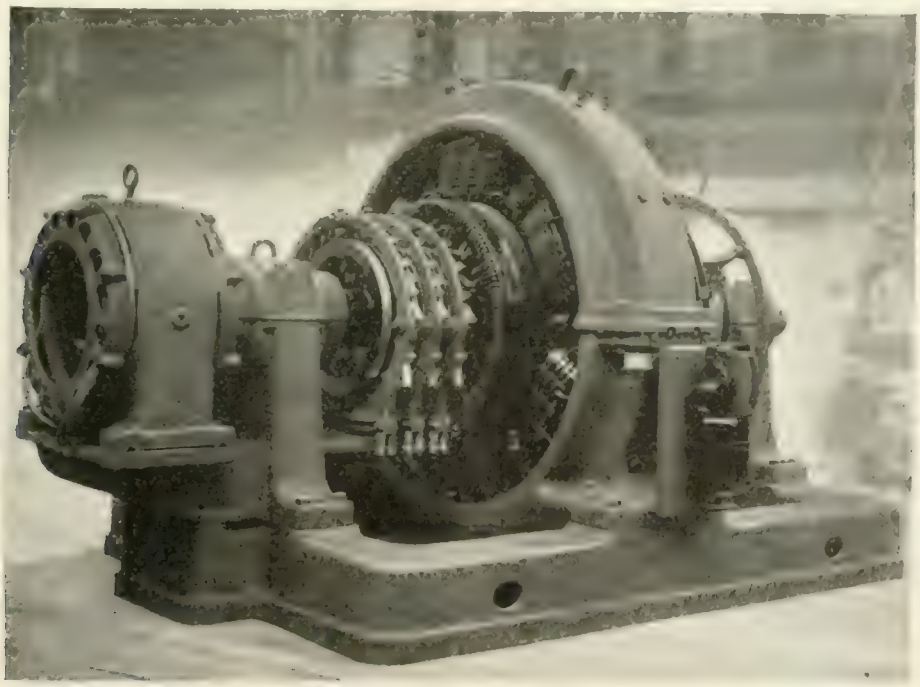


FIG. 9—VIEW FROM DIRECT-CURRENT END OF ROTARY CONVERTER SHOWN IN FIG. 8

It is not intended here to touch on the developments in commutating pole converters for sixty cycle supply or for variable voltage lighting service. The discussion of these developments will be left to a subsequent article. The examples given, however, show how rapidly the application of this class of machine is extending into the railway service where the supply is at twenty-five cycles.

LOCOMOTIVES FOR ELECTRIC MINE HAULAGE

IMPORTANCE OF DETAILED INFORMATION COVERING OPERATING CONDITIONS

G. W. HAMILTON

Much has been written on the subject of mine haulage from the viewpoint of the commercial engineer, dealing with locomotives required to handle a maximum output over maximum grades and distances during the working hours of the day. In the present article the author discusses some of the details which control this output, and in consequence the design of the locomotives.—[Ed.]

IT IS a simple problem to estimate the weight and capacity of a locomotive which will haul a certain output in, say, eight hours, but if the details of operation from face to tipple are not careful considered, the output secured when the locomotive is installed may fall far short of that planned. That such trouble and disappointment may be avoided, the conditions throughout the mine should be obtained and the locomotive designed to meet them, bearing in mind that a successful plant is one in which equal service is given to all engaged in the same work, the majority of the men being paid by the ton or car.

To illustrate this problem in a simple way two estimates will be given covering the equipment required to handle the output of a mine similar to those located throughout central Pennsylvania, the first one being based on incomplete data received through correspondence, and the second one on data secured by a visit to the mine.

ESTIMATE NO. 1

Data Furnished:—

1—Gauge of track, 42 inches.
2—Weight of rail per yard, 40 lbs.
3—Radius of sharpest curve, 25 ft.
4—Weight of empty car, 2 000 lbs.
5—Weight of load in car, 4 000 lbs.
6—Maximum grade against loads, 3 percent.
7—Length of haul, one way, 3 000 ft.
8—Output wanted per day, 1 200 tons.
9—Working time per day, 8 hours.
10—Voltage, 500 volts, direct-current.

From this information the locomotive required for the work may be estimated as follows:—

Output 1 200 tons per day, which at two tons per car, requires 600 cars. Length of round trip 6 000 ft., which at an average speed of 600 ft. per minute, will require 10 minutes for running time, or 20 minutes for a round trip, allowing 5 minutes at each end of the run for coupling up, releasing car

brakes, etc. With twenty minutes per round trip, a total of twenty-four round trips may be made in 8 hours, and to secure the output wanted twenty-five cars must be hauled per trip. As no record of the length of the maximum grade has been given it is assumed that the locomotive will pull the twenty-five loads on the 3 percent grade, which must therefore be at least four hundred feet long. The frictional resistance of the cars is taken as thirty lbs. per ton, and of the locomotive as twenty lbs. per ton.

To haul 25 loads, each weighing three tons, or a total of 75 tons, up a 3 percent grade, allowing 60 lbs. per ton for the resistance due to grade, and 30 lbs. per ton for the resistance due to friction ($75 \times 60 + 30 = 6750$), will call for a running drawbar pull of 6750 lbs. Using a 12 ton locomotive, allowing 60 lbs. per ton for resistance due to grade, and 20 lbs. per ton for resistance due to friction, it requires for its own operation a tractive effort of 960 lbs. ($12 \times 60 + 20 = 960$). Then the total tractive effort required equals 7710 lbs.

In the absence of further data covering the grades throughout the trip, with their lengths, the frictional resistance of the cars, etc., the square root of the mean square current of the motors in service cannot be figured, and the equipment placed on the locomotive should be powerful enough to mount the maximum grade with full load of cars, permitting little if any overload on the basis of the one-hour rating of the motor equipment. On reaching the mine it was found that, while the twelve ton locomotive in use was amply able to haul twenty-five cars per round trip and make three round trips per hour, it could not secure the output desired, and a visit to the mine resulted in securing the following information, which will make up the second estimate.

ESTIMATE NO. 2

Data Secured:—

1—The output is hauled from eight cross headings and rooms by four gathering locomotives, each one hauling to the main parting from 140 to 160 cars per day.

2—Number of cars loaded per working room per day, 5.

3—Number of cars loaded at face of each cross and main heading per day, 7.

4—Time occupied by each gathering locomotive in making a round trip with 14 to 16 cars, from rooms and face of cross headings to main parting, from 40 to 45 minutes. (Loaded cars gathered from rooms on one cross heading, and empties placed in rooms on another cross heading each trip, .)

5—Frictional resistance of mine cars, from 20 to 24 lbs. per ton.

6—Location of main parting now 3000 ft. from tipple, but in the future will be 4200 ft.

7—Grades, maximum 3 percent against load for 600 ft.

8—Two of the gathering locomotives work on the east side, and two on the west side of the main north heading, which is the main road.

With each gathering locomotive reaching the main parting with an average of fifteen loads every forty-five minutes, or ten times per day, if the main haul locomotive made a round trip from tipple to parting every twenty minutes with twenty-five cars, it would not serve them efficiently, and frequently would have to wait at least half an hour before hauling its first trip of loaded

cars to the tipple. This condition would be apt to occur the first thing in the morning when the majority of the empty cars were in the rooms or cross headings, and while the time lost during the first hour could be offset by making higher speed with the empty trips, and cutting the extra time from ten to eight minutes per round trip, it would continue to occur throughout the day, and would have the effect of causing dissatisfaction among all employees.

To avoid such trouble the main haul locomotive should be designed to place on the parting enough empty cars per trip to serve two of the gathering locomotives simultaneously, or in this proposition from thirty to thirty-two, and make an extra trip if desired to prevent any reduction in the output from unavoidable delays.

The schedule will then be as follows for each round trip:—

Maximum number of loaded cars per trip	32
Maximum number of round trips per day	20
Minimum length of round trip	6 000 ft.
Running time at 600 ft. per minute	10 min.
Time allowed for coupling up, delays, etc.	14 min.

A round trip can readily be made to and from this parting in twenty minutes and, as in nineteen round trips 1 216 tons may be secured, a margin of 100 minutes is obtained, if each trip is made on schedule time. When the parting has been located 4 200 feet from the tipple, the schedule per round trip will be:—

Maximum number of loaded cars per trip	32
Maximum number of round trips per day	20
Maximum length of round trip	8 400 ft.
Running time at 600 ft. per minute	14 min.
Time allowed for making couplings, etc.	10 min.

As 1 216 tons can be hauled in nineteen round trips of thirty-two cars each there will be, when running on easy schedule, twenty-four minutes to spare for delays, or a maximum output of 1 280 tons in eight hours.

To haul thirty-two loads up a three percent grade (the resistance due to friction being 24 lbs. per ton) will require a running drawbar pull of 8 064 lbs., and with a 14 ton locomotive a tractive effort of 9 184 lbs., as against a 12 ton locomotive developing a tractive effort of 7 710 lbs. in Estimate No. 1.

This problem is given to show the value of detailed information on all the conditions which influence haulage of any kind, and while the correct solution of a given proposition may call for extra work at the outset, this method will result in most cases in a saving of time and money when the equipment has been installed.

SINGLE-PHASE COMMUTATOR MOTORS

TYPES INVOLVING USEFUL INTERNAL TRANSFORMER ACTIONS

R. E. HELLMUND and E. W. P. SMITH

IN a former article were considered the action of the main field flux of a single-phase commutator motor on the coils short-circuited by the brushes, and the effect of the current in them due to the voltage caused by the main field. Under certain conditions this short-circuit current is very destructive and at all times is objectionable. The action causing it may therefore be classed as a detrimental or useless transformer action as distinguished from a transformer action which may be made to assist in extending the design or operating limits. The present article has to do chiefly with the useful transformer actions in the motor, the application of which has resulted in the development of various different schemes of connection as exemplified by the following:

1—Series motor with short-circuited compensating winding.

2—Repulsion motor.

3—Double-fed series motor.

4—Motor with armature excitation (Winter-Eichberg motor.)

SERIES MOTOR WITH SHORT-CIRCUITED COMPENSATING WINDING

For the purpose of explaining this motor type, reference should be made to a previous part of this series in which the purpose of the compensating winding was explained.* It was there shown that the compensating winding serves to eliminate or compensate for the cross field set up by the armature current. It was also pointed out that the best effect is obtained if the compensating winding not only eliminates the armature field as a whole, but is arranged in such a manner as to counterbalance exactly the armature field at each individual point of the armature circumference. To obtain this result, it is necessary to distribute the compensating winding over the pole face in a way similiar to the distribution of the armature winding over the armature. The compensating winding, therefore, has to have a number of current conductors per unit of circumference equal to the number per unit of armature circumference, and the current in the compensating winding has to be the same as in the armature. The latter condition is fulfilled by connecting the auxiliary winding in series with the armature, as diagramatically indicated in Fig. 1a.

*See the JOURNAL for Feb., 1912, p. 131.

The condition of equal ampere-turns for the compensating winding and the armature can also be obtained sufficiently close for all purposes if the compensating winding is short-circuited on itself as shown in Fig. 1b, instead of being connected in series to the armature. It will be remembered that if any two coils or windings are interlinked with a common alternating flux, the ampere-turns in the two coils are always equal and opposite to each other, if the magnetizing ampere-turns setting up the flux are neglected. If, therefore, the conditions of design are chosen such as to require only a small magnetizing current, it can be said that the ampere-turns of the two coils are practically equal and opposite to each other. The arrows and other signs indicating the current direction in the compensating winding of Fig. 1b have been entered under this assumption, and it will be seen that the current conditions in all the windings of Fig. 1b are exactly the same under these assumptions, as in Fig. 1a. Therefore, the operation of

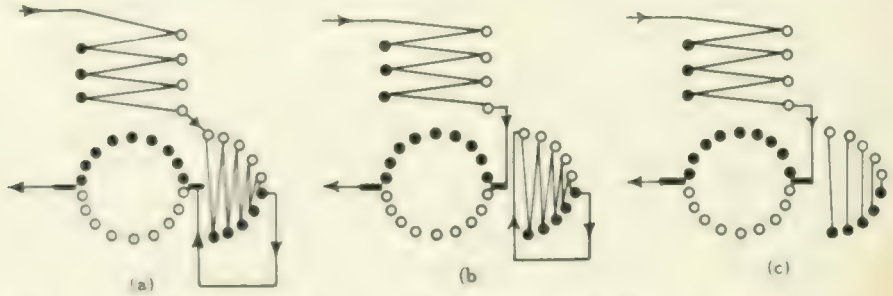


FIG. 1 (a), (b) AND (c)—DIFFERENT CONNECTIONS OF COMPENSATING WINDING

a motor connected as per Fig. 1b should be the same as with a motor connected as per Fig. 1a. Instead of short-circuiting the compensating winding on itself as a whole, it is also possible to connect each turn or coil of the short-circuited winding on itself as indicated in Fig. 1c and obtain similar results.

Even if the small magnetizing current which is necessary to induce the common alternating cross flux interlinking with the armature and compensating windings is taken into account, the operation of the motor with short-circuited compensating winding is practically the same as for the motor with series connected compensating winding. The reason for this is that this common cross flux needs to be only large enough to induce a voltage in the compensating winding which is sufficient to drive the current of the compensating winding against the counter-electromotive forces

which represent the ohmic drop and a small reactance voltage existing due to leakage fluxes around the compensating winding. Since both of these voltages are very small, the voltage to be induced in the compensating winding is also very small. Consequently the cross flux interlinking with the compensating winding, and the magnetizing current necessary to set up this flux are exceedingly small.

These statements will be borne out by the diagram of Fig. 2 which shows respectively the current and voltage relations of a motor with inductive compensating winding and one with conductive compensating winding under conditions as they actually occur in practical designs. If it be assumed that in this figure *Ic* represents the current flowing in the auxiliary winding, there will be

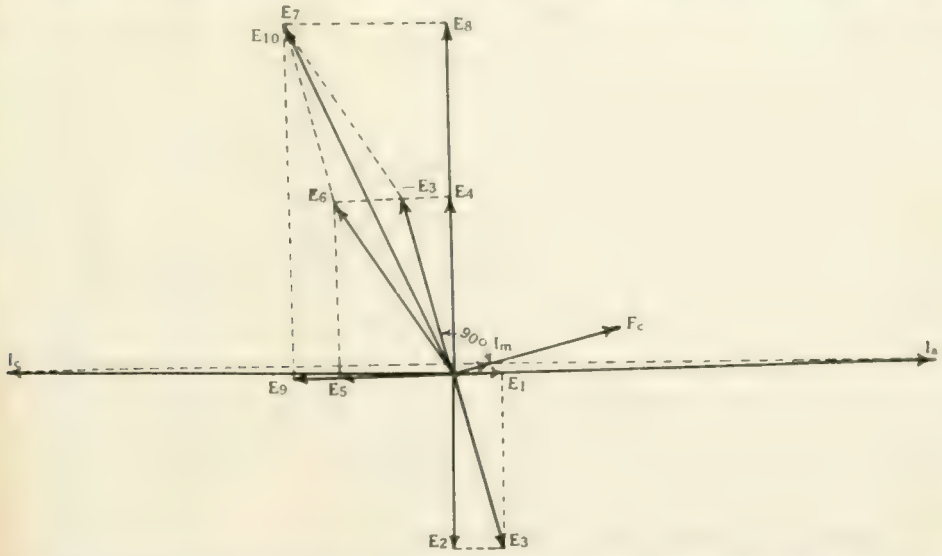


FIG. 2—VECTOR DIAGRAM SHOWING CURRENT AND VOLTAGE RELATIONS OF A MOTOR WITH INDUCTIVE AND ONE WITH CONDUCTIVE COMPENSATING WINDING

an ohmic drop E_1 which is in phase but opposite in direction to this current. There will, moreover, be a reactance voltage E_2 caused by the leakage lines of the compensating winding which lags 90 degrees behind the current. The two voltages E_1 and E_2, combine to give the voltage E_3, and in order to have the current *Ic* flowing, the cross flux will have to induce a voltage $-E_3$ in the compensating winding. Therefore, this will require a cross flux *Fc*, whose phase is 90 degrees ahead of the voltage $-E_3$ or lagging behind E_3 by 90 degrees. In order to set up this flux, it is necessary to have a resultant magnetizing current *Im* which is in phase with the flux. This magnetizing current is the resultant of the compensating current *Ic* and the armature current *Ia*, as shown in Fig. 2. In this figure, the magnetizing current *Im* which

is required to give the required flux Fc, has been taken from actual tests, and it will be seen that with these actual conditions, the current Ia is practically equal and opposite to the current Ic. In order to take the remaining ohmic drops into account the vector E_5 must be considered in the diagram. This vector E_5 represents all the ohmic drops caused by the current Ia, and is therefore in phase therewith but opposite in direction. In a like manner, the vector E_4 takes into account the reactive voltages caused by the leakage fluxes of the main circuit and it therefore lags 90 degrees behind the current Ia. The vectors E_4 and E_5 may be combined to the vector E_6 as shown. It must moreover be considered that the cross flux Fc not only induces the voltage E_3 in the compensating winding, but that it induces the same voltage in the armature (equal number of turns being assumed in both windings). The voltage $-E_3$ must therefore be added to the other voltages induced in the armature: thus, by adding E_6 and $-E_3$ vectorially, the voltage E_7 is obtained. The total motor voltage is then obtained by adding to E_7 the voltage induced in the armature by the main field due to rotation and due to the reactive voltage induced by the main field in the field winding. This has not been done in Fig. 2, as these two latter voltages are very large as compared with the voltage E_7 and would fall outside of the available space.

With this same vector diagram, Fig. 2, the case of the series connected compensating winding may now be considered. In this case all of the ohmic drops, including the one in the compensating winding may be represented by a vector E_{5a} in phase with and opposite to the motor current which, as before, may be represented by the vector Ia. All the leakage reactance voltages including the one in the compensating winding may be represented by a vector E_{4a} 90 degrees behind the motor current Ia. The voltages E_8 and E_9 combined give the voltage E_{10} to which should again be added the voltage induced by rotation and the reactive voltage of the field winding, in order to obtain the total motor voltage. It will be observed, however, that the voltage E_{10} is practically the voltage E_{5a}, from which it follows that the total motor voltages will also be practically alike, since the voltage induced by rotation and the voltage induced by the main field in the field winding will be alike in both cases as the current flow through the field and therefore the field strength will be the same in both cases.

Correct actual figures in the case under consideration showed that the voltages E_{5a} and E_5 are within 0.2 volts of each other and

that the only difference caused thereby is a change of the motor power-factor of less than one-tenth of one percent. The output of the motor will be the same in both cases since the armature current (and therefore the torque) as well as the field, must be the same, and since, moreover, the speed of the motor must be the same because in each case the voltage induced by rotation as well as the flux are the same.

The effect of the small cross field *Fc* on the commutation is of no account. If the motor has no commutating poles it usually has an interpolar space opposite to the coils under commutation, and therefore the cross field cannot exist to any extent in the interpolar space. If a motor has commutating poles, separate cross fields set up by the commutating pole will properly take care of the commutation. It will, therefore, be seen from the present instance, which is typical, that there is practically no difference between the two motor types. The compensating winding is the same in both cases, except that it is connected in series in one case and short-circuited on itself in the other. The short-circuited compensating winding has, however, a number of very marked advantages over the compensating winding connected in series. As has been mentioned, the series compensating winding will only completely eliminate a cross field if it is in its arrangement an exact counterpart of the armature winding, that is, if it has the proper number of turns and the right distribution. This condition cannot always be easily fulfilled in practice, since it happens at times that an armature winding of the multiple type does not give a full number of turns per pole, while the compensating winding is preferably connected all in series, and therefore, will have to have a full number of turns. In some cases, also, the distribution cannot be made exactly right. Therefore it is often the case that either the armature winding or the compensating winding will be the stronger, as a whole or at certain parts of the circumference, and will set up cross fields in one direction or the other. This, in turn, will mean reactive voltages and a reduction of the power-factor. In contradistinction to this, the ampere-turns in a short-circuited compensating winding will always be right because this is the case in any transformer no matter what the ratio of turns of the two windings may be.

If connections as in Fig. 1c are being used, not only will the right total ampere-turns be obtained, but the correct distribution will also result, no matter how the auxiliary ampere-turns are ar-

ranged, because in this case the current in each individual coil or turn can adjust itself to the exact value required. The arrangement of Fig. 1c is, therefore, preferable to any other. While, therefore, with a theoretically correct series compensating winding, the connections of Figs. 1 a, b, and c are alike in operation, better results are often effected, in actual practice, with the short-circuited types of compensating windings. Moreover, it is a marked advantage to be at liberty to arrange the compensating winding with a different number of turns than in the armature, as is possible with an individually short-circuited arrangement of compensating winding. This enables the designer to get the best mechanical arrangement for the compensating winding. Another, and even more important advantage of the short-circuited compensating winding, is the fact that it has practically zero voltage to ground and can, therefore, be constructed with less insulation, and that it will give practically no insulation troubles, or burn-outs consequent thereto.

It will, therefore, be seen that the short-circuited compensating winding, especially the arrangement of Fig. 1c, is always to be preferred to the series connected winding, except for cases where the motor is to be used on both direct and alternating current circuits. Whenever the motor is operated with direct current it will of course be impossible to make use of the transformer effect between armature and compensating winding, and, therefore, the latter has to be connected in series in order to be effective.

(To be continued)

THE SELECTION OF AN ELECTRIC FAN

H. M. SCHEIBE

FAN motors are so generally used and operate with so little attention that it is commonly thought that all fan motors are more or less alike and that little care is needed in their selection. Examination, however, of the various fan motors on the market indicates that there exists a wide difference, not only in fans of different manufacture but at times between different sizes and models from the same factory. The selection of a fan is made by two classes of purchasers, namely, the dealer who purchases in quantity from the factory and the user of the fan. As it is usually to a dealer's advantage to handle one line of fans exclusively, it follows that he should make his selection of that line with due regard to the customers' requirements. The following description will therefore treat the subject only from the standpoint of the user.

As in the case of larger apparatus, a fan motor should be selected with a view to the service which it is to perform as well as its initial and ultimate cost, and the service requirements should govern as to the size and type which is chosen. Portability, durability, cool running and adjustability should be insisted on. Neatness of appearance, and variety of finish will also appeal to the purchaser, especially when the fan is for use in the home.

The item of first cost ordinarily enters but slightly into the selection of an electric fan, as the prices of small fans of different manufacture are approximately the same. A slight difference in price should not, moreover, be given too great consideration as it may be that the more efficient fan will easily save the difference in price during a single season. Usually the one question which arises at this point is whether the fan should be purchased. For residence purposes this is simply a question of whether the convenience is worth the price. For office or factory use the question of greater efficiency of the workers on account of more comfortable surroundings is the determining factor.

Operating Costs—A few years ago fan motors were crude, clumsy and inefficient affairs, but active development by the various makers has resulted in great improvement. There still exists, however, sufficient variation to make a difference in operating costs in some cases of as much as ten percent of the first cost of the fan during each season. This saving represents a good invest-

ment of the time required to make a careful selection. It is worth while for dealers to check up the power consumed both by the fans they handle and also by fans of other types. No special apparatus is necessary to make input tests other than a low reading wattmeter and a voltmeter. It is of course, evident that all fans which are tested on the same circuit should be of the same rated voltage, as a fan which is designed for a lower voltage will take a larger current and deliver a greater volume of air than a fan built for a higher voltage.

Air Delivery—It must not be assumed that a fan with low current consumption necessarily delivers less air than one with a larger input, as a wide difference will be found, both in the efficiency of fan motors and in the efficiency of blades of different designs. A final judgment of a fan performance involves, of course, checking its air delivery against the power it consumes. Absolute air measurements can not be made without special equipment and elaborate tests and are at best of little interest to the fan user who is concerned only with comparative results. It is easy, however, to select the better of two fans in point of air delivery by either of two simple methods that can be used almost anywhere. It is suggested that dealers in fans will find it to their advantage to be in a position to make these simple tests at any time, not only in order to select the best fan to handle, but also to be fortified with first hand information on the apparatus that they sell.

The first test consists in placing the fan so that it will deliver a current of air exactly in a vertical direction. It should then be weighed on any ordinary scales graduated to ounces, first with the fan running at full speed and again at a standstill. The difference in ounces represents the thrust* with which the fan propels the air. Obviously only fans of the same blade diameter and same rated voltage should be used.

Another method, which is somewhat more direct, consists in placing the two competing fans face to face, about six inches apart, with the shafts in line with each other both vertically and horizontally. A piece of cardboard large enough to more than cover the whole face of the fan blades is held loosely by the top edge midway between the blades. With both motors running at full speed

*The thrust does not accurately represent either the energy delivered by the fan or the air displacement, but is an approximate mean between the two and consequently affords a good basis for comparison.

the card will swing toward the fan with the smaller air delivery. Care should be taken that the card is held midway between the blades and not necessarily midway between guards.

It is evident that an electric fan which is used for cooling purposes should not become excessively warm itself. Practically all fans on the market will operate continuously at a temperature very much below that required to injure the insulation. Other things being equal, a fan of lower operating temperature should be selected, as low temperature means low losses in the motor or a large current of air passing the motor, both of which features are desirable.

Noise.—A certain amount of humming is involved in the operation of any electric fan. Where slight noise is not objectionable and maximum movement of air is desired the ordinary four-bladed fan is to be recommended. If quietness is the prime consideration a six-bladed fan running about two-thirds as fast should be selected. All of the leading fan makers now offer such a fan for residence use. A great deal of difference exists in this respect, however, between different makes of fans, as by properly shaping the blades some manufacturers have been able to secure much more quiet operation than others without sacrificing air delivery.

Ready portability of a fan is obviously desirable. This means that it must be light of weight without sacrificing stability, and sufficiently rugged to withstand careless handling and carrying by the guards. A marked advance in portability has recently been made by the introduction of pressed steel motors. This construction has obvious advantages in point of light weight, neatness and ruggedness. At the same time, the smooth, close-grained metal surface lends itself to a variety of ornamental plated finishes not readily applied to cast iron.

Durability—Practically all of the large manufacturers of fan motors are now marketing apparatus that will operate satisfactorily under long continued periods of service. Probably no other class of rotating machinery receives less care and gives more uniformly satisfactory service than does the average fan motor. This statement is not necessarily true, however, of mechanically oscillated fans, as the oscillating mechanism necessarily involves a gear and link system, and the various types on the market differ widely in durability and in the facility with which wearing parts may be replaced. A link system that involves a long series of pin joints

is very liable to develop lost motion rapidly and this makes the oscillation short and unsteady, when the mechanism begins to wear. Gears should be few in number and readily replaced without using tools other than the ever present screw driver.

All fan motors should be given periodic cleaning and lubrication, although many of them seldom get it. This is very important if long and satisfactory service is expected.

Adjustability—Convenience demands that a desk fan be readily adjustable as to direction of air delivery and speed control. The fan should be stable on the desk when pointing in any ordinary direction, and it should be capable of being mounted on the wall if desired without using extra parts or tools. In the case of oscillating fans it is convenient to be able to start or stop the oscillation without stopping the motor.

Inasmuch as some of the foregoing considerations are to a certain extent conflicting, it is necessary to decide which features are of paramount importance. Thus too low first cost is not compatible with highest quality. Effective air delivery is difficult to secure without a certain amount of noise. There is no reason, however, why neatness of appearance, light weight, etc., should not be combined with low power consumption and adequate air delivery.

A fan motor should be selected to suit the service conditions just as much as a large piece of apparatus. For instance, a sixteen inch fan delivers a big breeze sufficient to circulate the air in a large office, but most fans of this size, when running at high speed, are entirely too noisy for use in a house or quiet private office. A twelve inch fan is usually adequate to any demand of house service, and several makers are marketing a special six-bladed slow-speed fan of this size especially for residence use where noise is very objectionable. The eight inch fan is also largely used as a residence fan, as it is very easily carried about and entirely adequate where large volumes of air are not needed.

AUTOMATIC MOTOR STARTERS AND CONTROLLERS

FOR DIRECT-CURRENT MOTORS

H. L. BEACH

AUTOMATIC control devices have a decided bearing on the selection of a motor for industrial applications, aside from and in addition to the actual service the motor has to perform. The operation of the automatic starter is very different from the usual operation of the hand starter, and a motor application which may be proper from the standpoint of the load and the hand starter may be entirely wrong when an automatic starter is used. As the construction and operation of hand starters and controllers are so well known that they need no description, they will be used to illustrate the operation of some of the more recently perfected automatic starters.

There are three different schemes used in controlling the operation of automatic motor starters: first, by a dashpot; second, by the counter e.m.f. of the motor, and third by series or current relays. Dashpot controllers are generally troublesome to maintain and are more or less affected by the weather. Counter e.m.f. acceleration is not always uniform as the switches are worked at their minimum operating "pull-in" point which will vary with the temperature of the magnet coils and with the general conditions of the switch bearings, etc. Current control in its various forms is the scheme that is most generally used and the one which will be considered in this article. In this scheme the operation of the switches is controlled by the current in the armature circuit of the motor. As the motor current decreases with the acceleration of the armature, a relay, whose magnet coil is in the same circuit, drops and closes an auxiliary circuit which includes the switch magnet coils and which is so arranged that it causes the switches to close consecutively. The relay is very sensitive and responds quickly to changes in current so that it interrupts the rapid progression of the switches as each step of resistance is cut out. A modification of this is found in the recently developed "self-closing" or "magnetic lock-out" switch in which current above a certain value saturates the main core of the switch and the extra lines of force pass through a parallel iron circuit and air-gap and hold the switch open until the motor current has fallen to the

value at which it is desired the switch shall close. The results of the two schemes of operation are identical and they do not enter into the discussion at hand.

The curves in Fig. 1 show the different speed characteristics of shunt, compound and series motors. These are theoretical curves based on an actual set of curves from a shunt motor and calculated so that at a full load of 100 amperes the field saturation, the speed and the torque of the three motors correspond. It will

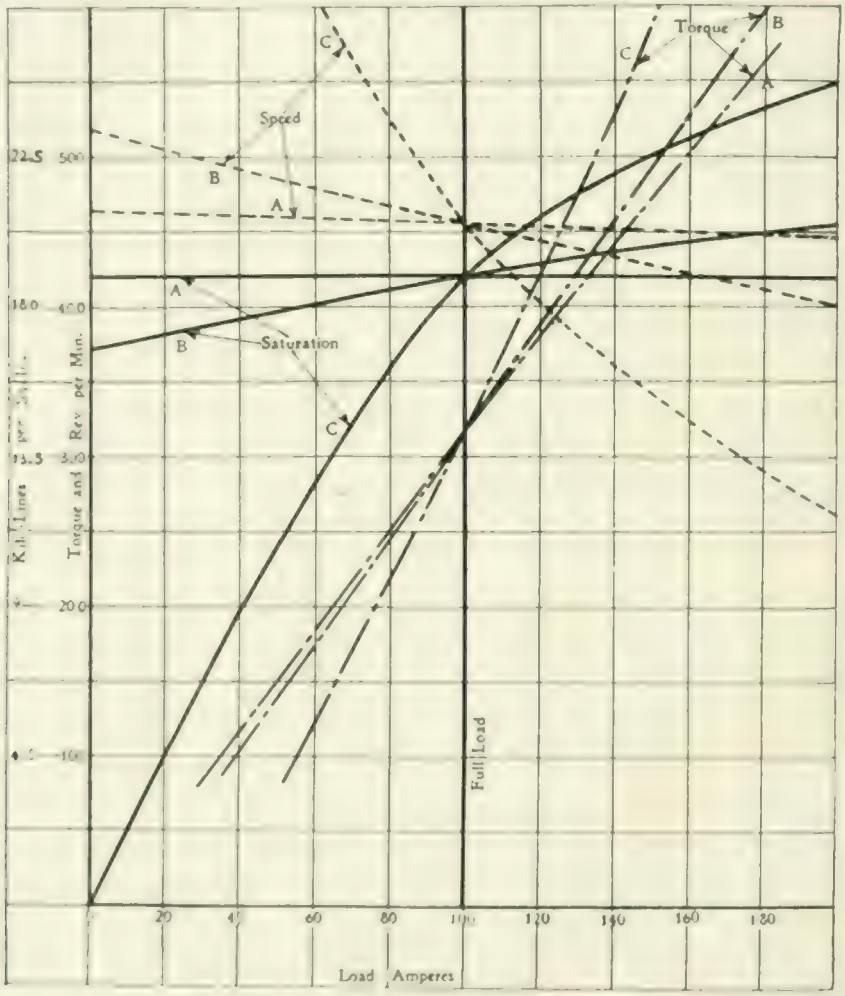


FIG. 1—SPEED, SATURATION AND TORQUE CHARACTERISTICS OF DIRECT-CURRENT MOTORS

A—Shunt motor.
B—Compound motor.
C—Series motor.

be observed that the shunt motor speed varies but little from no-load to full load and such speed variations as are shown may be considered as caused by the resistance drop in the motor armature which increases with the load. The compound-wound motor, however, has a considerable drop in speed with increase of load. This is caused first, by the resistance drop of the circuit carrying the

armature current, (which is greater than that of the shunt motor due to the addition of the series field), and second, by the change in field strength due to the effect of the armature current in the series field winding. In a standard compound motor the series field ampere-turns at full load are about 20 percent of the total field ampere turns of the motor. In the series motor there is no constant field excitation to assist in steadying the speed and it therefore varies with the load, the speed characteristic curve being determined largely by the saturation curve of the motor field; in fact, the speed curve of the series motor is practically an inverted saturation curve corrected for resistance drop in the motor windings.

In starting a motor by means of a hand starter the operator simply moves a contact arm across a row of buttons. One man will do this in 5 seconds, another in 20. No knowledge is had of what is occurring in the motor or in the line during this operation, and the motor may be badly overloaded or may come up to speed on the first button and run on resistance during the rest of the acceleration period. If an ammeter be connected in the circuit the operator can see what happens and will usually find that he operates the starter quite differently than he did before he had the meter.

Starting Shunt Motors—When starting a 25 horse-power, 220 volt shunt motor as in Fig. 1, suppose that with the ammeter in view the operator moves the starting handle quickly to such a point on the starter that the current rises to 165 amperes. Since the motor is standing still there are no armature volts and therefore the current is controlled entirely by the resistance in the circuit. This is composed of three elements, viz., the armature resistance, the resistance of the motor leads and the starting resistance. For 165 amperes at 220 volts this would be 1.33 ohms. The operator now holds the handle on this button until the current falls to 100 amperes, i.e., full load. The resistance has not changed so that the resistance volts must be only $I \times R = 100 \times 1.33 = 133$, and the only thing that can have changed is the armature voltage. The motor must, then, have come up to a speed corresponding to an armature voltage of $220 - 133 = 87$ volts (with a shunt motor the field strength may be considered of constant value so that the speed is directly proportional to the armature volts). The operator now moves the handle until the ammeter again reaches 165 amperes. This means

that he has cut out some of the starting resistance. Assuming that this is done on one quick step, so that the motor speed does not change while it is being done, the total resistance volts, viz., 133 volts, remain momentarily unchanged, and therefore the total resistance left in the circuit is $133 \div 165 = 0.81$ ohms; that is, the operator has cut out 0.52 ohms. If now the operation continues as before, the current will fall to 100 amperes with only 81 resistance volts and 139 armature volts. Another step should cut out 0.32 ohm, leaving 0.49 ohm, and the current again rises to 165 amperes. Another step cuts out 0.193 ohm, leaving 0.297 ohm, while another step will cut out 0.117 ohm and leave 0.18 ohm, which will closely approximate the resistance of motor armature and leads. In no case has the current exceeded 165 amperes nor been less than 100 amperes, which in this case is full load on the motor. Since the field has not varied, the actual torque of the armature is directly proportional to the armature current and has, therefore, fluctuated directly with the current changes. If the load has been light, the motor has come up to speed very quickly and the operator has moved the starter handle very fast. If a heavy load, it has come up to speed slowly and the operator has moved the starter handle slowly. The current changes are exactly the same in the two cases, and the strains on the shafting are identical.

A simple set of calculations will show that, if 165 amperes starting current is considered too high for a 100 ampere load, the only way to reduce it is to have more points on the controller. If resistance is added to the first step to get say only 140 amperes instead of 165 ($220 \div 140 = 1.57$ ohms), and the resistance on the second step left unchanged, then when the current falls to 100 amperes, and the starter handle is moved to the second step, a resistance of 0.70 ohm will be cut out instead of 0.52 ohm. There were 1.57 ohms, however, before this step was cut out, so that the resistance volts were 157 instead of 133, and the current with 0.81 ohm on the second step would at once rise to 194 amperes instead of 140 or even 165. Therefore, it is seen that any change on any one step to reduce the current on that step, will raise it correspondingly above normal on the next unless changes are made in all the steps.

Starting Compound Motors—In considering the foregoing an armature resistance of 0.1 ohm was involved. It is very conservative to allow 0.08 ohm additional resistance in conductors,

switch connections, etc., bringing the total up to 0.18 ohm. With a compound-wound motor there is an additional motor series field resistance of about 0.025 ohm, or 0.205 ohm total motor resistance. From the saturation curve *B* of Fig. 1 for a compound motor it will be noted that the change in flux from full load to 1.65 load is 6.4 percent. Then for a change in series field strength of 65 amperes load, the counter volts would change 6.4 percent if the speed did not change.

Considering the same set of conditions as with the shunt motor, where there was a 65 ampere change at each step, the total resistance at first will be as before, i.e., $220 \div 165 = 1.33$ ohms and when the current falls to 100 amperes, there will be 133 resistance volts and 87 armature volts. When the first step of resistance is cut out to allow the current to rise to 165 amperes the armature volts will change and rise to 106.4 percent of 87 volts or approximately 92.5 volts, so that the resistance volts will be only $220 - 92.5 = 127.5$ volts, instead of 133, as with the shunt motor. The resistance left in the circuit will equal 127.5 : 165 amperes = 0.77 ohm; i.e., 0.56 ohm has been cut out in this step. Continuing the calculation and remembering that the armature volts increase 6.5 percent each time a step of resistance is cut out, the second resistance step is found to be 0.36 ohm, which leaves 0.41 ohm in the circuit, 0.205 ohm of which is motor resistance, which means that 0.205 ohm is left in the starting resistance. Cutting this out will raise the current to about 150 amperes instead of 165, so that it will be seen that three steps of resistance with a compound-wound motor can be arranged to give a slightly smaller peak than four steps with a shunt motor.

Starting Series Motors—In considering the starting characteristics of a series motor, it is necessary to refer to the saturation curve for the counter e.m.f. change, as this curve is not a straight line. At 100 amperes the density in the motor considered is 18.9 kilo-lines per sq. in., while at 165 amperes it is 23.4 kilo-lines per sq. in. As $23.4 - 18.9 = 4.5$ or 23.8 percent of full load saturation, the armature volts will therefore increase 23.8 percent every time the current rises suddenly from 100 to 165 amperes. As before, $220 \div 165 = 1.33$ ohms and $1.33 \times 100 = 133$ resistance volts or 87 counter volts, while $1.238 \times 87 = 107.7$ counter volts at 165 amperes, which leaves only 112.3 resistance volts. Hence, there are 0.682 ohms left, 0.648 ohms having been cut out. When the current again falls to 100 amperes there will be 0.648 ×

100 = 64.8 resistance volts and 157.2 armature volts. If sufficient resistance is now cut out of circuit to allow the current to rise to 165 amperes the 157.2 armature volts will rise to 1.238 × 157.2 = 194.5 volts, leaving 25.5 resistance volts which is sufficient only for 0.155 ohm. Referring to the paragraph *Starting Shunt Motors* it will now be found that the armature resistance equals 0.1, and that .08 ohm was allowed for leads, etc. There will now be 0.1 ohm additional series field resistance, which brings the total resistance up to 0.28 ohm, i.e., more than the value of 0.155 above calculated. On the third and last step the current, will, therefore, not rise to 165 amperes but to only about 130 amperes.

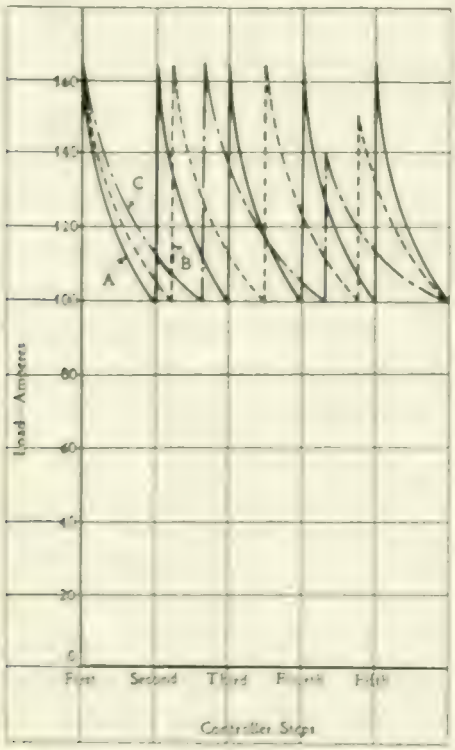


FIG. 2—NUMBER OF STEPS REQUIRED TO LIMIT THE ACCELERATING CURRENT TO A GIVEN VALUE WITH; *A*—SHUNT MOTOR, *B*—COMPOUND MOTOR, *C*—SERIES MOTOR

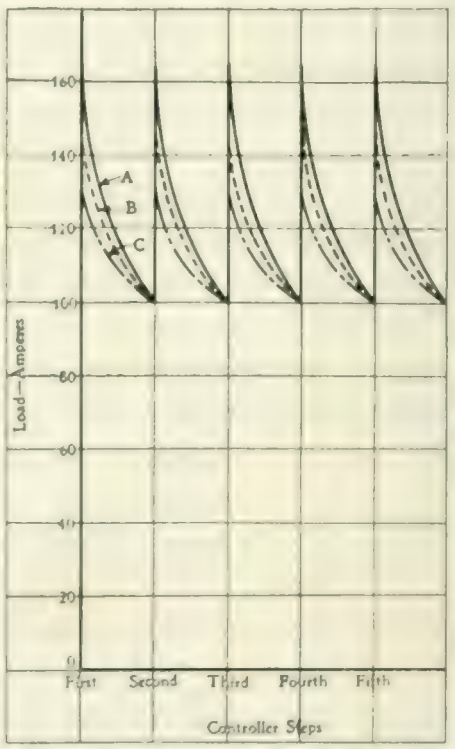


FIG. 3—CURRENT INCREMENTS PRODUCED BY A GIVEN NUMBER OF CONTROLLER STEPS WITH; *A*—SHUNT MOTOR, *B*—COMPOUND MOTOR, *C*—SERIES MOTOR

By plotting curves of the foregoing, the results shown in Fig. 2 are obtained. If new calculations be made to determine what peaks are obtained on the different motors with the same number of steps, the results shown in Fig. 3 are obtained. The actual grading of the resistance is quite different for the three motors, as is seen when the calculated results of the determinations for Fig. 3 are plotted to give the curves of Fig. 4. Subtracting the values of line and armature resistance from the total values of resistance at each step, Fig. 5 is obtained which shows

that the resistance for a shunt motor will not give equally good results with a compound motor or with a series motor and that a series motor resistance used with a shunt motor will not give current enough on the first notch and will give a very high peak on the last notch.

AUTOMATIC OPERATION

If the operation of an automatic starter be examined it will be found that it simply serves to do mechanically what the operator does by hand with the hand starter and ammeter. The relay operates the starter when the current reaches 100 amperes and

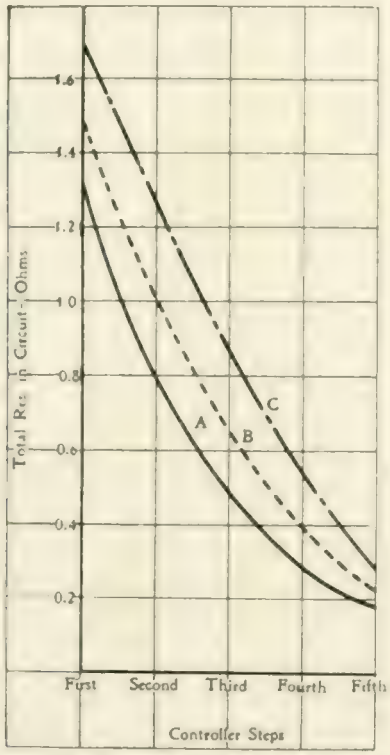


FIG. 4—TOTAL RESISTANCE IN CIRCUIT ON EACH CONTROLLER NOTCH

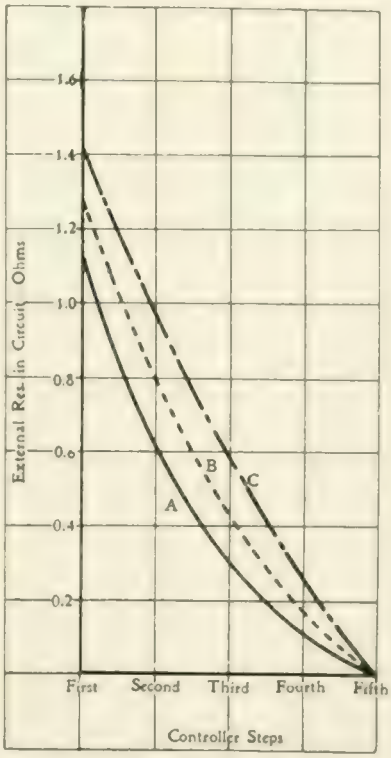


FIG. 5—CONTROLLER RESISTANCE IN CIRCUIT ON EACH CONTROLLER NOTCH

the value to which the current rises is controlled entirely by the resistance left in the circuit. A properly graded resistance should give entirely satisfactory and invariably the same results. Practical tests show that the current as read by an ammeter will not rise to as high a value as calculated. This is due largely to the lag of the ammeter needle and also to the inductive and armature reaction effects in the motor, which tend to smooth out the peaks. With a sensitive ammeter, however, the peaks will be seen to be the same at each step, which shows that the calculations are reliable and give a fairly clear indication of what happens each time the starter is operated.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

762—Testing of Lightning Arrester—What is a suitable test for lightning arresters, such, for example, as the Lord lightning arrester? E.P.M.

We consider a suitable test to be the duplication of lightning conditions, as nearly as possible. This can be obtained by discharging through the arrester a static charge from a condenser of capacity equal to that of say 10 miles of line, or 1.0 micro-farad. The equivalent gap can then be measured, as described in the JOURNAL for Apr., 1905, p.224. Under some conditions, a hold-over test by power voltage can be made, to determine how well the arrester stands up under static discharge while power is on the arrester, as also described in the above reference. Note also, article on "Protection of Electric Circuits" in the Journal for Feb., Mar., and Apr., 1908, pp.79, 156, and 223. E.P.J.

763—Refusal of Motor to Start Under Load—Power is received at a sub-station at 13,200 volts, transmitted 2.5 miles at 2,200 volts to a second sub-station, and from there to a 100 hp, 220 volt induction motor, at a distance of 700 ft. The motor will carry 40 hp with a voltage of 210 volts. When the load is increased, however, the motor current goes to over 100 percent above normal and the voltage drops to 170 volts at the motor. At the same time the voltage at the 2,200/220 volt transformers drops to 100 volts. Three transformers are connected for two-phase—three-phase transformation. Is the trouble possibly due to poor regulation resulting from this connection? Otherwise please suggest cause and remedy for the trouble. C.H.S.

The low voltage may be due to excessive total line drop, or to poor regulation at the three-phase—two-phase transformers. If the transformer units employed for such transformation are not properly connected internally to give balanced conditions on the respective magnetic circuits of the units, poor voltage regulation may result, as pointed out in an article on "Magnetic Leakage in Transformers," by Mr. E. G. Reed, in the JOURNAL for May, 1910, pp. 407, 408 and 409. However, if the load conditions are such as to cause the motor to draw 100 percent in excess of normal current, it would seem that the motor may not be of sufficient capacity for the work. A motor of about twice the rating of the present one would probably remedy the trouble, even considering the poor voltage regulation.

764—Car Braking by Bucking Motors—Is it possible to stop a car having an equipment of two direct current motors, a series-parallel controller, circuit breaker, etc., by bucking the motors, i.e. by shutting off power, opening the circuit breaker, throwing the reverse handle around and then bringing the controller handle to full-on position? "A" claims that it can be done. "B" claims that it cannot be done with direct current motors, but neither one is in a position to prove his point, and we would therefore appreciate a full explanation as to just what does take place. L.W.M.

It is entirely possible to stop a car equipped as described, by opening the circuit breaker, throwing the reverse handle, and moving the controller up to the "full parallel" position. The braking action is due to the fact that under the conditions described, the two motors

become series generators, driven by the momentum of the car. If any external circuit were provided, such for example as in the case where rheostatic braking or electric track brakes are employed, the two machines would tend to feed current in parallel into this external circuit. Under the circumstances described, however, there is no external circuit and the machines, therefore, tend to feed each through the other, and as there are always sufficient inequalities in material or variations in other conditions in two such motors to cause a difference in the voltage generated by them when operating as generators, the machine having the slightly higher voltage will probably overcome the other, and feed current back through it in the reverse direction. This will reverse the polarity of the second machine, which then causes the two machines to become generators in series instead of in parallel, delivering power into a dead short-circuit. The mechanical power required to drive the two machines as generators acts as a drag on the car, and tends to stop it, and if these connections are produced with the car running at any considerable speed the stop will be a very violent one. This action is independent of the direction in which the car is running, as long as the reverse switch is thrown; that is, if the car is operating in the forward direction, driven by the motors, the reverse switch must be put into the backward position in order to secure the braking effect. If the car is operating in the backward direction, driven by the motors, the reverse switch must then be put in the forward position in order to secure the braking action. In the case of a four-motor equipment, since the two motors of each pair are permanently connected together in parallel, without passing through the controller drum, it is only necessary to throw the reverse switch after opening the circuit breaker without the necessity of moving the controller handle into the parallel position in order to obtain the braking action, as is necessary on a two-motor equipment. If the car is moving at any considerable speed when the motors are reversed, as described above, some peculiar phenomena are likely to occur. For instance, the current will probably be so great that the wheels of the car will slip, and they will then revolve more slowly than the speed of the car would normally require. Probably also, either one pair of wheels will slip and the other not, or one pair will slip more than the other, in which case the pair which slips the most will tend to slow down, stop and reverse. Under these conditions, the machine connected to this pair of wheels ceases to be a generator, and becomes a motor driven by current from the other machine; and this gives rise to the peculiar condition of a car moving along with one pair of wheels revolving forward and this other pair backward. C.R.

765—Relation of Name Plate Rating to A. I. E. E. Standards—On what particular classes of apparatus may the rating on the name plate of the apparatus be accepted as the standard A. I. E. E. rating for the better known makes of apparatus; or, if easier to answer, which may *not* be so accepted? The Westinghouse Cooper-Hewitt Rectifiers—(30 amp., and 50 amp.,) have ratings of "Volts, Amperes," "Number of Cells," etc., on the name plate. Are these normal operation ratings, maximum ratings or what? What I wish is to get at the proper horse-power rating under A. I. E. E. regulations for such apparatus; that is, such rating that the apparatus will stand 25 percent overload for two hours with 15 degrees C. temperature rise, etc. Also, the same question in regard to elevator motors. For example, with Otis elevator motors, what relation does the name plate data bear to a proper A. I. E. E. rating for this apparatus? If there is a definite fixed ratio in each case, what is this ratio approximately? A.F.S.

The question is difficult to answer for the reason that different types of apparatus may be rated on a very different basis. The average

apparatus manufactured may be said to be rated on a temperature rise of 40 degrees above the surrounding air for continuous full-load working conditions, with an additional temperature rise of ten to fifteen degrees C. (total of 50 to 55 degrees) for a 25 percent overload for two hours. The American Institute standardization rules provide for limits of from 40 to 65 degrees C. rise, based on a room temperature of 25 degrees C., and an additional 15 degree rise for an overload of 25 percent. It may be said that apparatus in general will meet these conditions or better, but the actual relation of the temperature rise in any given piece of apparatus to the Institute standard requirements can be obtained only by test of the apparatus in service, or by reference to the maker's tests. In general the ratings on name plates are the normal operating ratings. The operation of Cooper-Hewitt rectifiers is based on a normal temperature rise of 50 degrees C. There is no way in which a horse-power rating can be given to a battery charging or an arc light rectifier, which will indicate in any way its capacity. The same thing is just as true in trying to give a horse-power rating to the battery, as it must be rated in ampere-hours and number of cells. An arc light rectifier is rated in ampere capacity and number of lamps. A battery charging rectifier is rated in maximum amperes and maximum number of cells which can be charged. There is also sometimes given a maximum voltage, but this maximum voltage cannot be taken simultaneously with the maximum current rating. The ratings are so given as to indicate the size and number of cells that can be charged and, as the batteries in general require a tapering charge rate, the maximum voltage will always be required at one-third to one-half the maximum current rating, and for that reason a rectifier rating based on horse-power is meaningless. For specific purposes the average horse-power when charging the largest number of cells for which the outfit is suited can be indicated, but this has no relation to an A. I. E. E. horse-power rating. For information regarding the relation of the Institute standard requirements to the name plate on the Otis elevator motors, we would suggest that you confer directly with this Company.

C.E.S. and R.P.J.

766—**Electrical Dictionaries**—Please inform me whether there are any up-to-date electrical dictionaries published, which give all of the latest technical terms, such as load factor, station factor, diversity factor, etc. I have Houston's Dictionary, but not in sufficiently revised form to cover some of the later electrical terms.

F.P.M.

Houston's dictionary of "Electrical Words, Terms and Phrases" has been published in revised and enlarged form in a fourth edition, containing 990 pages, 582 illustrations, and sells at $7.00 net. If the older edition is the one referred to in the question, this later edition would doubtless fulfill your wants. Note also the "Illustrated Technical Dictionary" published in two volumes in English, German and several other languages. This dictionary is classified somewhat like a handbook, according to subjects. Volume II, compiled by Chas. Kinzbrunner, deals specifically with electrical engineering, including telegraphy and telephony. This volume contains some 2,100 pages and 4 000 illustrations, indexed alphabetically; price $7.00 net. Note also the "Electrical Dictionary" by T. O'Connor Sloane, twelfth edition, 682 pages, 393 illustrations, containing some 5 000 words, terms and phrases, carefully indexed; price $3.00 net. The latest revised information regarding technical and electrical terms will probably be found in the revised standardization rules of the American Institute of Electrical Engineers, which may be obtained in pamphlet form for a nominal price from the Secretary of the Institute, 33 West 39th Street, New York City. See also report of the Committee on Terminology of the National Electric Light Association.

E.R.S.

PERSONALS

Mr. H. L. Sampson, chief electrician for the South Utah Mines and Smelter Company, of Newhouse, Utah, has resigned to enter the construction department of the Southern California Edison Company.

Mr. Yasuhiro Sakai, for eight years on the engineering staff of the Westinghouse Electric & Manufacturing Company at East Pittsburgh, has returned to Japan where he is to open a consulting engineering office in Tokyo.

Professor William E. Barrows, of Armour Institute of Technology, has resigned to accept the position of professor of electrical engineering at the University of Maine, Orono, Me.

Mr. C. B. Cook, who has been connected with the publicity work of the Westinghouse Machine Company, East Pittsburgh, Pa., has severed his relations to accept a position with Ford, Bacon & Davis.

Mr. H. C. Burd, sales engineer of the Standard Underground Cable Company, at their New York office, has been appointed assistant to the sales manager of the Standard Underground Cable Company of Canada, Ltd., with headquarters at Hamilton, Ontario.

Mr. W. J. Kyle, of the Chicago district office of the Westinghouse Electric & Mfg. Company, has resigned to accept a position with the H. M. Byllesby Company.

Mr. J. M. Leslie, of the engineering department, Canadian Westinghouse Company, Hamilton, has taken up commercial work in the Toronto office of the same company.

Mr. R. G. Berle, formerly of the Cincinnati office of the Westinghouse Electric & Mfg. Company, is now connected with the Los Angeles district office.

Mr. E. D. Kilburn, of the Buffalo office of the Westinghouse Electric & Mfg. Company, has resigned to enter the employ of the Westinghouse Machine Company.

Mr. Alfred Still, who left England in the early part of last year to take up the position of electrical engineer to the Lake Superior Power Company of Sault Ste Marie, Ontario, Canada, has lately been appointed chief electrical engineer to the mining department of the Algoma Steel Corporation. His headquarters will be at Magpie Mine, Ontario, where he will have charge of the very complete and up-to-date electric power equipments at the various mines controlled by the company, and will also be responsible for the completion and operation of the 4,000 horse-power hydro-electric generating station connected to the mines through an 18 mile three-phase overhead transmission.

Mr. C. L. Speaks, of the East Pittsburgh works of the Westinghouse Electric & Mfg. Company, has been transferred to the Charlotte office.

Mr. William H. Marsh, who for the past ten years has been connected with the Standard Underground Cable Company of Pittsburgh, in the capacity of superintendent of construction, has been appointed sales manager of the Standard Underground Cable Company of Canada, Ltd., with headquarters at Hamilton, Ontario.

Mr. C. D. Kunkel, of the East Pittsburgh works of the Westinghouse Electric & Mfg. Company, has been transferred to the Seattle district office.

Professor C. A. Johnson, of the department of electrical engineering of Kansas State University, is spending the summer months in the general engineering department of the Westinghouse Electric & Mfg. Company at East Pittsburgh.

Mr. Edward E. Ashley, Jr., and Alfonse Kaufman have opened consulting engineering offices at 417 Fifth Avenue, specializing in the design of heating, lighting, ventilating, refrigerating and sanitary installations.

Woodcraft for July, 1912, contains a reprint of the article by Mr. William B. Wreaks on "The Proper Procedure in Factory Electrification" from the JOURNAL for June.



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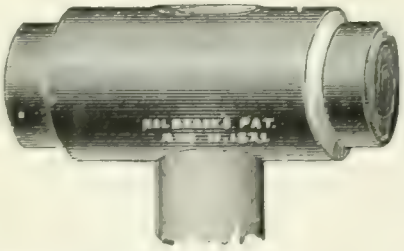
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PENNSYLVANIA ELECTRIC ASSOCIATION

The fifth annual convention of the Pennsylvania Electric Association will be held on September 4, 5 and 6 at the Bedford Springs Hotel, Bedford Springs, Pa. Among the papers to be presented are the following:—"The Prone Pressure Method of Resuscitation from Electric Shock," by Dr. C. A. Lauffer; "The Wiring of Old Houses," by Messrs. McKirdy and Wood of Pittsburgh; "Dollars and Factors," by Mr. C. J. Russell, of Philadelphia; "Welfare Work," by Mr. B. F. Day, of Philadelphia. Addresses are to be made by F. M. Tait, president of the National Electric Light Association, and Mr. T. Commerford Martin, executive secretary. A number of attractive entertainment features have been arranged.

NEW BOOKS

"Engineering Valuation of Public Utilities and Factories"—Horatio A. Foster. 345 pages, Published by D. Van Nostrand Co., New York City. Price, $3.50.

The interest in the subject of property valuation is being greatly accelerated by the increasing number of states which have created commissions to exercise supervision over companies operating public utility enterprises. Rate regulation has for one of its important factors the earning of a fair profit on a reasonable investment valuation, covering both the physical property and the intangible costs. There have been published from time to time appreciable literature bearing upon the topics of value, valuations, good-will, going concern, depreciation, amortization, appreciation, capitalization, etc., which has been embraced in this book, but has hitherto been much scattered over engineering proceedings, court decisions and technical magazines. The condensing of the most important and valuable of these within one cover proves of much worth for reference and study. Approved forms adopted by the Wisconsin Commission after a most careful investigation have been reproduced very nearly in full. Mr. Foster, who became widely known through his Electrical Engineer's Pocket Book, has been a party to several extensive utility investigations and consequently acquired much experience in this field first hand. Mr. Foster's work is characterized by its degree of thoroughness.

E. D. D.

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The Development of Electrical Machinery

Both the article by Mr. Dick entitled "Notes on a Large Unipolar Generator" in the present issue of the JOURNAL, and the paper by Mr. Lamme on the "Development of a Successful Direct Current 2000 kilowatt Unipolar Generator," presented before the Boston Meeting of the American Institute of Electrical Engineers, are indicative of the rapid changes which are taking place at the present time in the development of electrical machinery. Those who are closely identified with the manufacture of electrical products like to feel that the time is rapidly approaching when designs will become standardized and manufacturing problems simplified, but it is questionable whether such is the case. At the time the design of the generator in question was undertaken, it seemed the only solution of the problem from an economical standpoint, and similar developments were going on in all the large electrical manufacturing companies. However, before the machine was in commercial operation, developments in other directions pointed to the fact that the solution could be arrived at more economically in other ways, and it is not probable that this type of unit will ever have a very large application.

There is another viewpoint often lost sight of in connection with developments of this nature where, as in this case, the need is no longer felt, namely, the credit due the designers for successfully solving a most difficult problem. Some of the troubles that presented themselves seemed almost impossible of solution, but, as pointed out in Mr. Lamme's paper, they were taken care of one by one as they came up, and the final result was a most successful machine which has been in almost constant operation day and night since it was put in commercial service. Had the demand for this type of unit continued, the development would have been heralded as a great achievement in machine design, instead of being lost sight of as a mere incident in the day's work. The time and expense

of the development was by no means lost as the data obtained is applicable to other classes of apparatus and there is no doubt but that the utilization of this data will eventually more than pay for it.

W. K. DUNLAP

Proving the Circuit-Breaker

Increased economy results from the use of the large generating units, and practically every central station man is therefore vitally interested in the determination of the features which limit the maximum capacity of apparatus that can successfully be placed in service. The article by Mr. J. N. Mahoney in this issue of the JOURNAL giving the results of tests on large high voltage circuit breakers, will relieve any doubt in the minds of central station men that the circuit breaker might be a limiting feature.

In this instance, we have, first, a central station as a martyr willing to risk its entire plant for a cause by which all central stations will profit, and, second, a manufacturer making expenditures for which he can hardly be expected to receive remuneration within the course of a reasonable time.

Probably never before in the history of the electrical industry have such exhaustive and comprehensive tests been made on any piece of apparatus under practical conditions as in this case, and the result is that circuit breakers are now available for the protection of plants of any capacity and voltage and with a time element as low as nine-hundredths of a second, to meet all practical conditions. From the knowledge obtained by these tests, the problem of securing satisfactory circuit breakers for the protection of central stations resolves itself into a question for central stations to determine as to the time in which they desire the circuit breaker to open.

C. E. ALLEN

The Selection of Mine Locomotives for Gathering

The question of efficient and economic handling of coal in the mine, of increasing the daily output and decreasing the cost per ton mined is the vital question that confronts every coal mine operator. Electric haulage locomotives are in common use, for every up-to-date mine is electrified, and coal operators are fast coming to a general realization that the function of gathering the loaded cars from the various working faces of the mine and distributing the empty cars to these points can

be accomplished more quickly and at less cost by electric gathering locomotives than by any other means.

No machine will do its work efficiently and with the highest economy unless in its application all of the various phases of the operating conditions have been taken into intelligent consideration. Mr. G. W. Hamilton, in this issue of the JOURNAL, shows in a very comprehensive manner the data that should be investigated and considered in deciding on the size and capacity of a locomotive for gathering service. Such a locomotive, like any other piece of apparatus, should not be installed in a hap-hazard manner and be expected to do its work efficiently.

There is a tendency to offer machines that are much heavier than required for gathering service. All unnecessary weight requires an additional amount of power to move it, causes extra wear on wheels, journals, brake shoes and track, besides cutting down the continuous capacity of the electrical equipment. Often too, the electrical equipment of the locomotive is of greater horsepower capacity than is advisable. This necessitates running on resistance the greater part of the time, and with the attending troubles, defeats efforts toward efficiency and economy. Locomotives, like shoes, should not be too small nor too large, but should fit conditions exactly.

Operators should insist that every locomotive that is installed in their mines be suitable for the service and that the fact of its suitability be established by a thorough investigation of the operating conditions.

L. G. SCHUMACHER

NOTES ON A LARGE UNIPOLAR GENERATOR

W. A. DICK

A paper on "The Development of a Successful Direct-Current 2 000 Kw. Unipolar Generator" was presented by Mr. B. G. Lamme before the American Institute of Electrical Engineers at Boston, Mass., June 28th, 1912. This machine is unique in many particulars especially as to type and size and the many new engineering problems involved. These problems and the ways in which they were solved are very completely brought out by Mr. Lamme, and those interested in these features are referred to his paper. As this paper was devoted mainly to the difficulties in the design and development of this particular machine, it is thought that some comments as to the construction and performance of the unipolar type of direct-current machine, may be of interest.—[Ed.]

BRIEFLY stated a unipolar generator (also called homopolar and acyclic) may be defined as one where the conductors in which the voltage is generated cut a magnetic flux of one direction only and so the current set up by this voltage when the external circuit is closed is unidirectional. In an ordinary commuta-

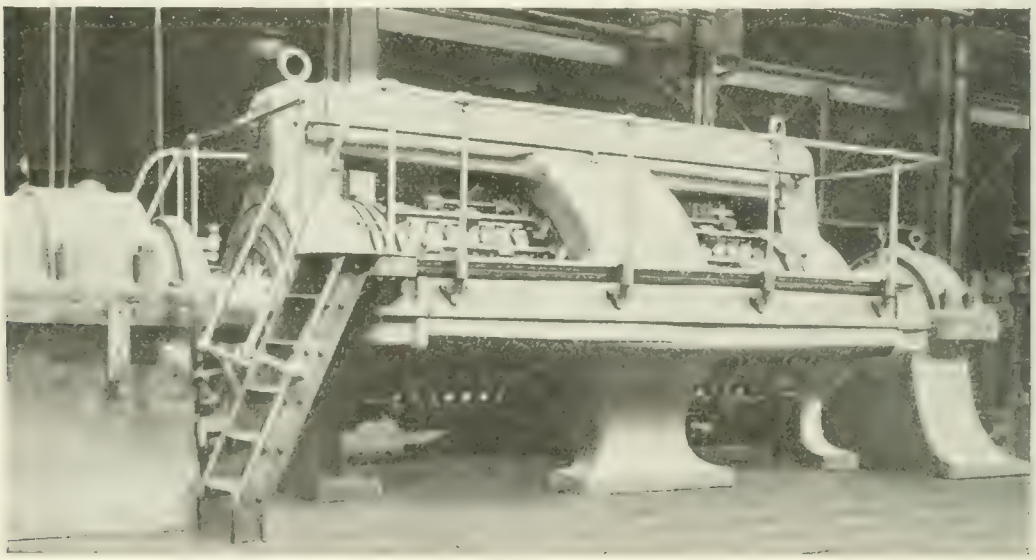


FIG. 1.—UNIPOLAR DIRECT-CURRENT GENERATOR
Capacity: 2 000 kw., 264 volts, 7 700 amperes, 1 200 r. p. m.

tor type of direct-current machine the voltage generated is alternating as the coils successively cut a flux of one direction under the north poles and of the opposite direction under the south poles. The current set up by these voltages when the external circuit is closed are rectified or made unidirectional by the commutator. The term "unipolar" is not strictly correct because there cannot be a magnetic circuit of one pole only, but it is the commonly accepted term for direct-current machines in which the flux cut by the armature conductors is unidirectional.

An external view of a 2 000 kw unipolar machine is presented in Fig. 1, and a detail view of its rotor is shown in Fig. 2. The output of the machine is 7 700 amperes at 204 volts and it is direct-connected to a steam turbine operating at 1 200 r.p.m. A diagram showing the relative proportions of the complete unit is given in Fig 3.

The operation of the machine may be seen from the sectional

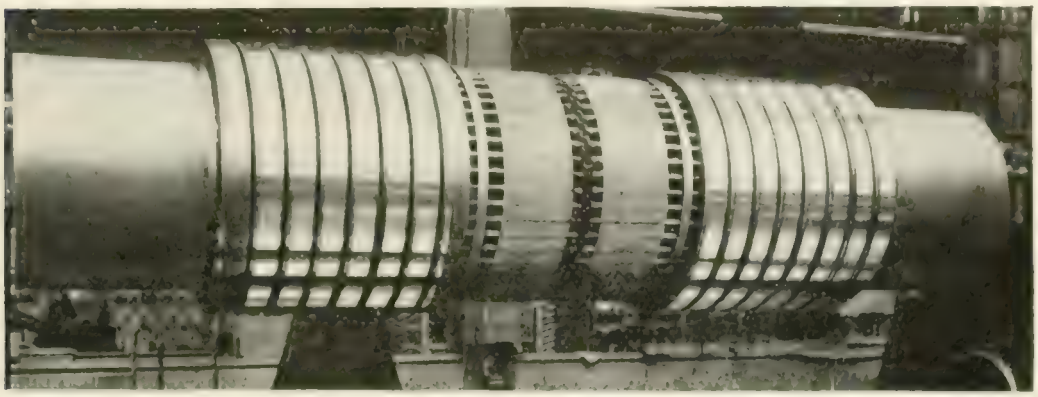


FIG. 2—ROTOR OF 2 000 KW. UNIPOLAR GENERATOR

view given in Fig. 4, in which both the magnetic and the electrical circuits are shown diagramatically, the arrows indicating the direction of the magnetic flux. From a study of the manner in which the conductors cut the lines of force the unidirectional character of the voltage can be seen.

The voltage that can be generated economically in this type of machine in any one conductor is comparatively small, as it is limited

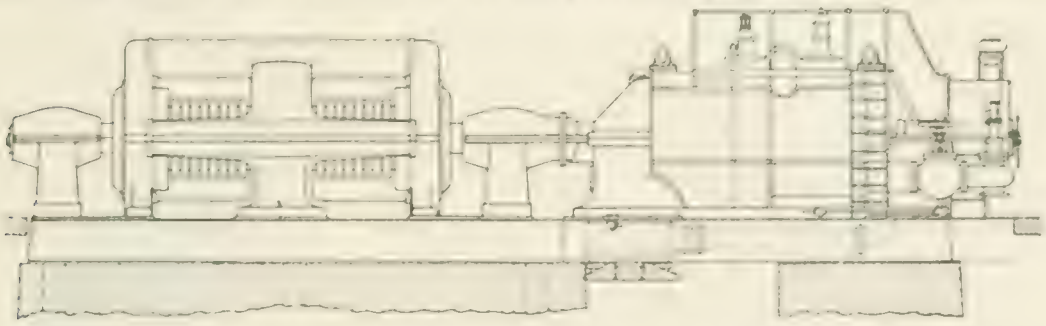


FIG. 3—DIAGRAMATIC ELEVATION OF UNIPOLAR GENERATOR
Showing relative proportions of complete unit.

by the magnetic flux which can be obtained from each pole. The magnetic flux is in turn limited by the cross-section of the magnetic circuit which cannot exceed a certain value without making the machine unnecessarily bulky and costly. If the voltage desired is greater than can be generated in one conductor, the number of conductors is increased and they are connected in series. In the present machine each conductor generates 32.5 volts and to secure the re-

quired voltage eight conductors are connected in series. As will be noted in Fig. 4, the return conductors are carried back through the stator in order to neutralize the armature reaction; armature reaction and iron loss are both reduced to a very low value. While Fig. 4 shows but one conductor between each pair of collector rings,

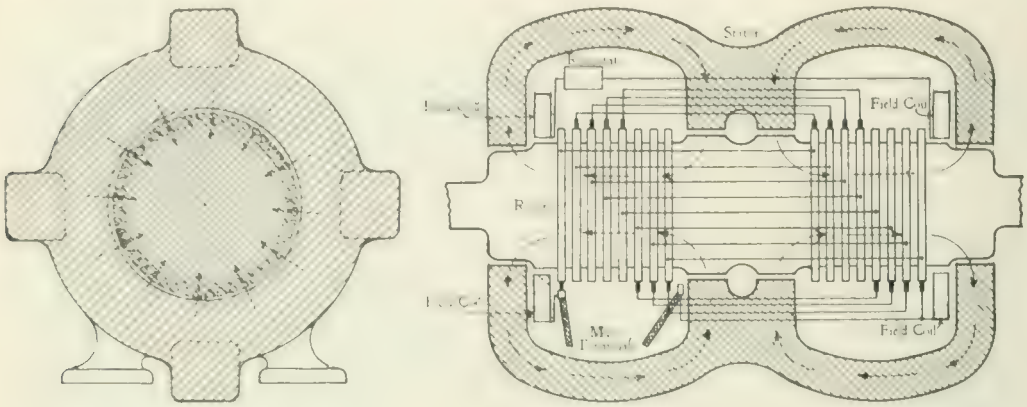


FIG. 4—SECTIONAL VIEW OF MAGNETIC AND ELECTRICAL CIRCUITS OF UNIPOLAR GENERATOR

The arrows indicate the paths of the magnetic flux.

there are, in fact, six bars in parallel, uniformly spaced. The ends of each group of conductors are attached to a pair of collector rings, one at each end of the rotor. It is evident that for this type of machine each conductor or group of conductors producing voltage requires a pair of collector rings. It is also evident that by paralleling successive groups of conductors, a greatly increased current output can be obtained at a correspondingly decreased voltage. With all circuits in parallel the output would be 61 600 amperes at 32.5 volts.



FIG. 5—CURRENT COLLECTING BRUSH

The current is collected from the rotating rings by means of stationary copper leaf brushes, of the type shown in Fig. 5, mounted on stationary rings as shown in Fig. 6. One of the principal problems of the design and development of the machine was to secure successful operation at the contact speeds required (over 2.5 miles a minute). After experimenting with numerous types of brushes it was determined that a thin copper leaf brush, very soft and flexible, with a suitable spring tension, would give very satisfactory results. One of the unique features of the machine was that it

was found necessary after numerous experiments to set these brushes against the direction of rotation in order to keep the rings clean, since the machine, as installed in service was subject to the dust of a cement works. Lubrication was supplied by very soft graphite brushes in insulated holders bearing on each of the rings.

The final design of the collector rings included a working ring and a superimposed wearing or contact ring. Both rings were shrunk on over heavy steel springs intended to take up any possible variation in tension produced by heating. In order to insure ample current carrying capacity the springs between the inner and outer rings were covered with a thin sheet of copper.



FIG. 6—SET OF BRUSHES MOUNTED ON STATIONARY RING

The final design of this generator has been commercially settled as it has been in successful operation for a number of years under somewhat adverse operating conditions in a cement plant, where it has proved its ability to operate without undue care or attention. The efficiency of the machine, shown graphically in Fig. 7, is very good for a generator of its current and voltage capacity. The temperature rise is less than 50 degrees C. on the rings and 40 degrees C. on all other parts. The points which require attention in operation are:—

1—Cleaning of rings at regular intervals with a four percent solution of hydrochloric acid.

2—Adjustment of brush tension to compensate for wear. About six pounds pressure per brush was found by experiment to give good operating results without excessive wear on either brush or collector rings.

3—Reversing the current at stated intervals, by switches at

the switchboard, to equalize the wear on the positive and negative rings. It has been found that the cement dust or some electro-chemical action has the effect of "eating away" the rings, which is greater when the current passes from the rings to the brushes than when it passes from the brushes to the rings.

4—Turning the rings to true them, in case any roughness should develop. This can be done without removing the rotor.

5—Cleaning the air passages by compressed air.

6—Replacing the brushes and collector rings at infrequent intervals, as they wear out.

The design of the generator has been made such that all parts requiring attention during operation are readily accessible, and all wearing parts are easily removed.

In the light of the statement of the successful operation of this

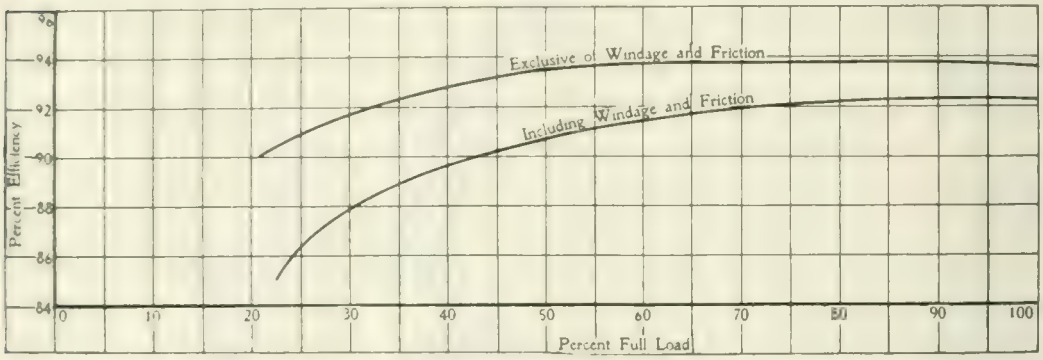


FIG. 7—EFFICIENCY CURVES
2 000 kw, unipolar generator.

machine, a question naturally arises as to why this type of machine has not been further manufactured commercially, and its use extended. At the time the order for this machine was taken it appeared that there was a field for large direct-current machines for direct connection to steam turbines, for installation in plants where large units are required, and that the unipolar type offered the best solution of the problem. The field still remains, but other more recent developments have taken the place it was thought the unipolar type of machine would occupy. These developments are along two lines and involve additions to existing types and lines rather than a new type, as follows:—

1—The development of higher speed alternating-current generators in large capacities, steam turbine driven. These are now being built in sizes up to 5 000 k.v.a., for 3 600 r.p.m. Rotary converters for transforming 60 cycle alternating-current to direct-cur-

rent are also available, and a combination of the two forms an attractive way of obtaining direct current in large amounts. Where direct-current only is desired the generators and rotary converters have their alternating-current circuits permanently connected togeth-

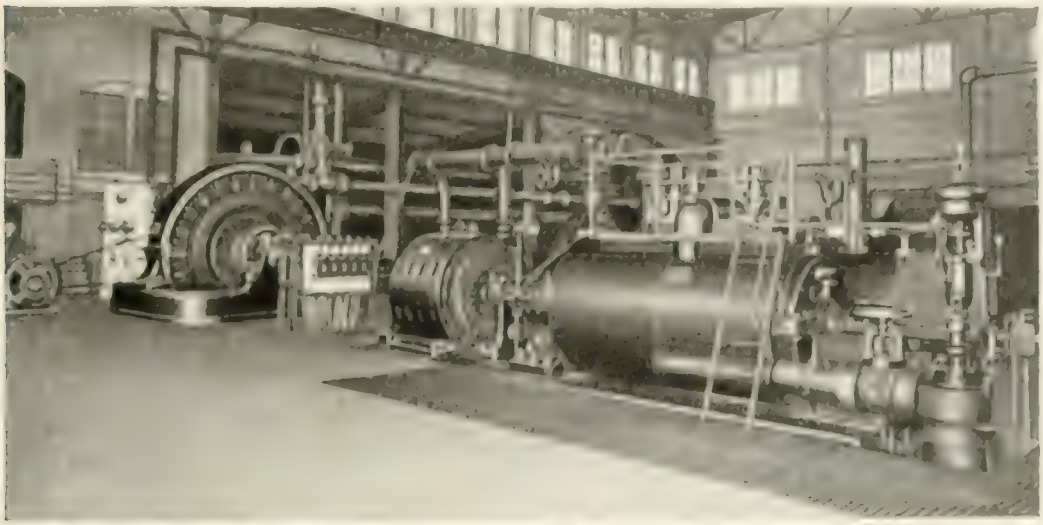


FIG. 8.—INDUCTION GENERATOR AND STEAM TURBINE SET ELECTRICALLY CONNECTED TO ROTARY CONVERTER FOR OBTAINING DIRECT CURRENT

er. The voltage of the generator is suitable for the rotary so that transformers are not required and both are operated practically as one unit, being started and stopped together. The improved efficiencies of the steam turbines due to the higher speeds offset the ad-

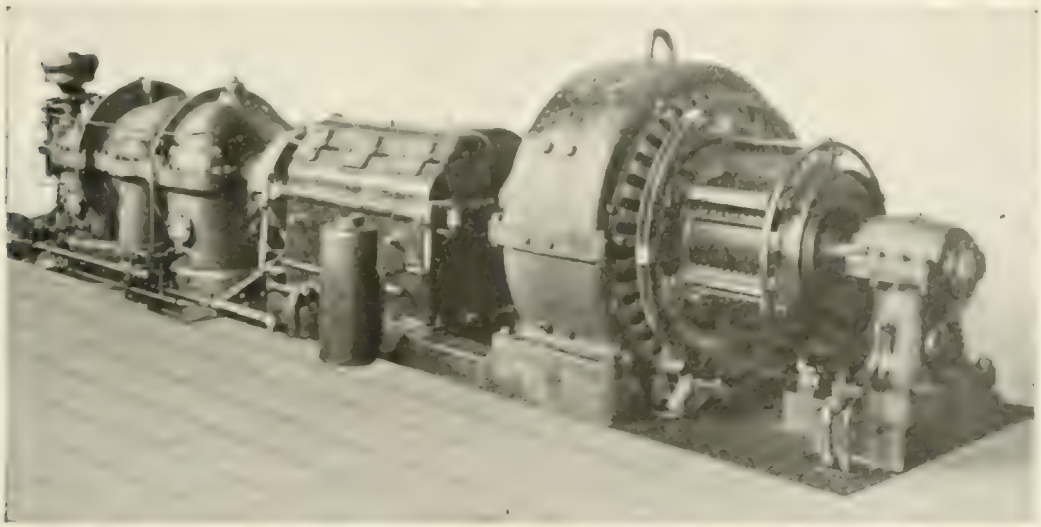


FIG. 9.—DIRECT-CURRENT GENERATOR GEARED TO HIGH SPEED TURBINE.

ditional losses in the second machine. A view of such a turbo-generator and rotary converter installation used for supplying direct-current only is given in Fig. 8.

II.—The use of large capacity direct-current machines of mod-

erate speeds, driving them by steam turbines through reduction gears. In this case the steam turbine operates at its most economical speed and the direct-current generator at an efficient and practicable speed for a commutation type machine. The gain in steam economy from the higher speed of the steam turbine more than offsets the losses in the gears. Gears for such drives are now in successful use, or are being built, in sizes up to 3 750 kw direct-current output. A 500 kw direct-current generator driven by a steam turbine through a reduction gear is shown in Fig. 9.

In both of these cases the steam turbines operate at higher speeds than would be possible with unipolar generators, and at somewhat better steam economies. The machines are all of standard types. The advantages of this arrangement are evident from the manufacturing and operating standpoint. The apparatus is also of types with which station operators are now thoroughly familiar. A new type always involves additional training and experience.

The unipolar type of machine is rather an expensive one to manufacture owing to the large amount of material required. The 2 000 kw machine weighs 175 000 lbs. The conclusion to be drawn regarding this type of machine is that it is an illustration of the case where an inherently satisfactory design is displaced through the development of other types which for various reasons excel it.

TESTS OF LARGE HIGH VOLTAGE OIL CIRCUIT BREAKERS

J. N. MAHONEY

AS THE outputs of generating stations have increased, it has become necessary to make important modifications of apparatus used to control or interrupt the flow of electrical energy in circuits connected to such plants. A type of apparatus that has been expected to operate satisfactorily under all conditions of operation is the circuit breaker. The modern oil circuit breaker must be of very rugged construction to withstand the severe mechanical and electrical stresses encountered in the operation of large capacity and high voltage power lines. It has become difficult to test large circuit breakers under operating conditions on large power systems except at great expense and the possibility of interruption of the power company's service; yet it has been imperative that there be some means of observing the operating characteristics of such apparatus under these conditions. An example of one such test is that made recently at the plant of the Hydraulic Power Company, Niagara Falls, N. Y., where the engineers, contemplating large extensions to their 12 000 volt service, instigated and later coöperated with manufacturers in such a series of tests.

These tests, completed during the latter part of 1911, are unequaled in point of magnitude of power and distributing equipment utilized. The operating engineers of the Hydraulic Power Company are to be commended for the very complete arrangements provided for making repeated tests under exact service conditions, thus making possible a new record in experimental electrical engineering under operating conditions. The results are far reaching from the standpoint of analysis of the requirements of modern central stations and in demonstrating the perfection of large switching apparatus to a point where it is capable of handling the output of the largest power systems. Other noteworthy tests which have been made in recent years may be of interest for the purpose of comparing the generating capacities utilized for test purposes and indicating the interest manifested on this general subject.

It will be seen from Table I that the machine capacity back of the tests at the Hydraulic Power Company's plant is approximately double that of the previous tests. The tests at Cos Cob and Chica-

go also had limiting reactances in series with the generator. The importance of the Hydraulic Power Company's tests, when considered from the standpoint of research in this field, may therefore be appreciated. Limiting reactance was not used and short-circuits were also made on a cable system of considerable dielectric capacity. In several of the tests the circuit breaker was introduced between the battery of generators and a large portion of the cable system. All load was removed and a short-circuit made on the end of the live cable system. Under these conditions, oscillatory surges and resulting voltage rises, due to the capacity reactance of the cable when added to the magnetic energy in the generator iron on cessation of the tremendous short-circuit current, make it much more difficult for the circuit breaker to fulfill its function.

TABLE I—TABLE OF CAPACITIES ON WHICH HIGH POWER CIRCUIT BREAKER TESTS HAVE RECENTLY BEEN MADE

Date	Capacity Tested K.v.	Machines, Voltage, and Systems
Feb., 1910	11 000	2 Machines—11 000 Volts. Long Island City Station, Pennsylvania R.R.
May, 1910 to March, 1911	16 000	4 Machines—11 000 Volts. Cos Cob, Conn., N. Y., N. H. & H. R. R.
Feb. to Mar., 1911	12 000	1 Machine—9 000 Volts. Chicago, Commonwealth Edison Co.
Aug. to Oct., 1911	50 000	4 Machines—12 000 Volts. Niagara Falls, Hydraulic Power Co.

STATION EQUIPMENT

The Hydraulic Power Company had installed, at the time of these tests, five 7 500 kilowatt, three-phase, 25 cycle, 12 000 volt horizontal water-wheel driven alternators running at 300 r.p.m. No changes were made in the bracing of the windings in anticipation of the repeated stresses which were to be produced by the severe short-circuits. One of these machines was always operated on a separate bus-bar carrying the commercial light and power load. The other four machines were usually operated on a furnace load and were available for test purposes both with the load on and off at various times. From one to four machines were utilized as shown in Table II, which gives a summation of the complete series of tests.

A total of sixty-two tests were made, in eighteen of which various amounts of load resistance were in series, the remaining

forty-four tests being closed short-circuits on the machine-room or on various combinations of cables. The majority of tests were made with a source of power of 22 000 and 30 000 kilowatts. During part of the tests on 7 500, 15 000 and 30 000 kilowatts of machines, all other load was disconnected, so that circuit conditions arising in the operation of this particular system could be reproduced.

TEST APPARATUS

Three types of circuit breakers were submitted by the manufacturers for tests. These were a standard "Type C" large oil-

TABLE II.—SUMMARIES OF TESTS AT NIAGARA falls

No. of Operations	Power in Kilowatts	No. of Tests	Special Provisions	
				Cables in Series
1	7500	2		1 m
1	7500	2		0
1	15000	1		2 m
1	15000	1		2 m
1	15000	1	Oil Unbaffled Non-Arcing	2 m
1	15000	1		1 m
1	15000	1		0.25
1	15000	1		0.37
1	15000	1		0
1	22500	1		1 m
1	22500	1	Oil Primary Coal	0
1	22500	1		Cables added
1	30000	1		1 m
1	30000	1		0.25
1	30000	1	Oil Unbaffled Non-Arcing	0
1	30000	1		Cables added
1	30000	1	Oil Primary Coal	0
1	30000	1		Cables added

pacity, remote control circuit breaker (an essentially smaller current breaker, but with improved details which are interchangeable with those of the type "C," and a new type of circuit breaker with larger dimensions than the standard. The manufacturers also supplied the necessary testing instruments and equipment, and a corps of skilled testers.

The arrangement of these circuit breakers, as installed on the roof of the Hydraulic Company's power house, is shown in Figs. 1 and 2. The circuit breaker on the extreme left in Fig. 1, is the standard type "C," used as a test circuit breaker and giving instantaneous automatic action from series transformers and relays set

direct-current trip coils. The center circuit breaker was used non-automatically as a closing switch to short-circuit the line. The breaker on the right is the newer type used as an automatic instantaneous direct-acting alternating-current trip circuit breaker. The rear view of Fig. 2, shows the load resistance used on some of the tests. This view also shows the voltage transformers across the contacts of each pole, the secondaries being connected to the voltage elements of oscillographs. The current transformers are to be seen at the extreme right of Fig. 2, on the cables. They were housed in place by timbers to prevent movement. The relay trans-

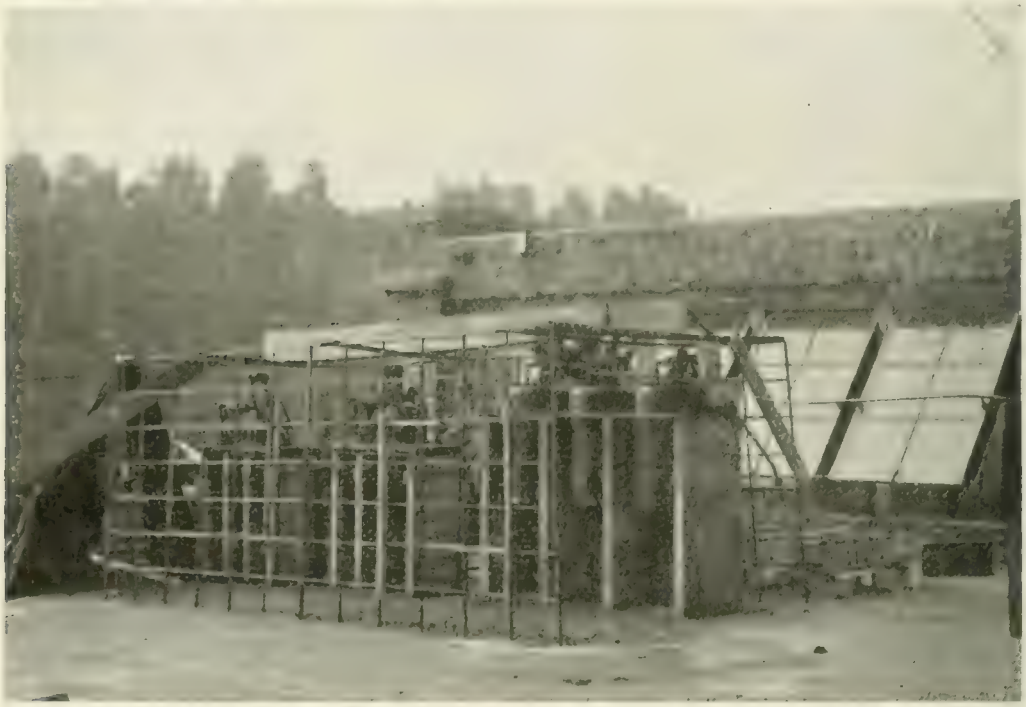


FIG. 1—ARRANGEMENT OF TEST CIRCUIT BREAKERS ON ROOF OF HYDRAULIC POWER HOUSE

formers are also visible on the incoming cables just ahead of the current transformers.

These views show clearly the heavy bracing required for the 500 000 circ. mil cables, since the magnetic fields resulting from direct short-circuits on generators totaling 30 000 kilowatts in capacity are capable of producing considerable whipping of large cables. The circuit breakers were all of the indoor type, so that during showers or at night they were covered with heavy canvas, which explains the iron work supports at the front and back of the circuit breaker structures.

Slightly elevated from the test roof level and inside the station back of the windows shown in Fig. 1, a platform was constructed

on which were mounted two oscillographs and the testing control panel. Each of the oscillographs was of the three element type, and they were so connected that three voltages and three currents of the three-phase circuit were recorded. They were arranged end to end, one motor driving the film holders of both at the same speed. On the control panel were mounted controllers for the operation of all test circuit breakers and switches, instantaneous relays and a field trip switch, to be used only in case of emergency.

The accuracy with which oscillographic records may be interpreted depends upon the care given to calibration. For these par-

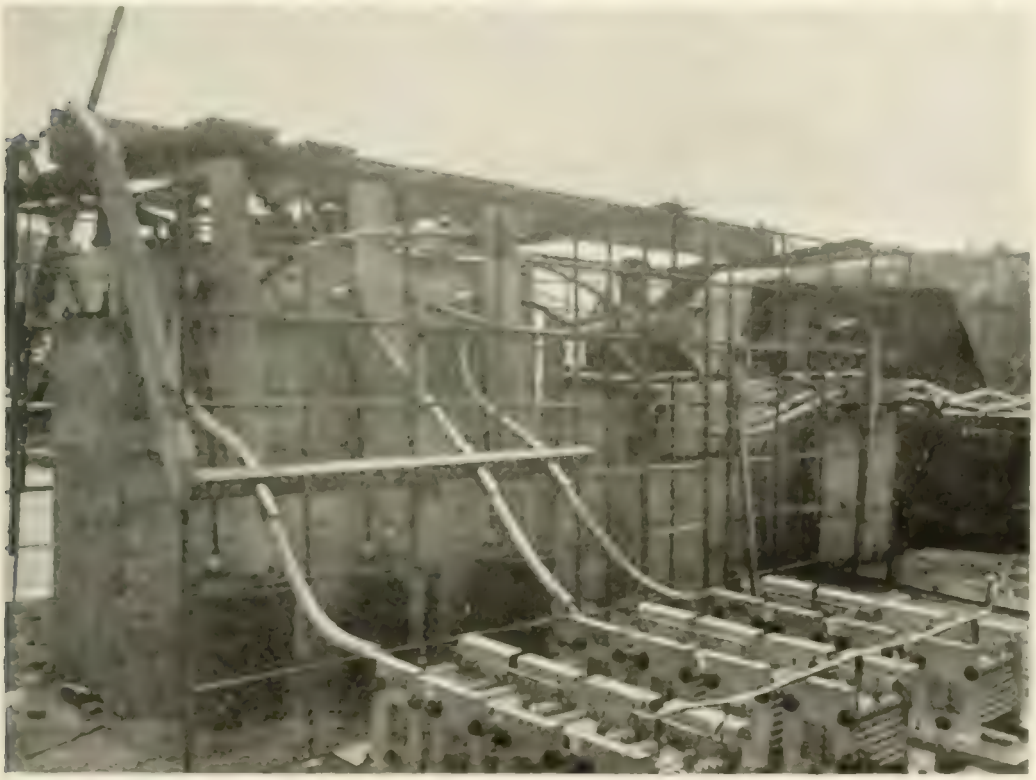


FIG. 2—REAR VIEW OF TEST CIRCUIT BREAKERS, SHOWING CONNECTIONS AND GRID RESISTORS

ticular tests, 3000 to 5 ampere series transformers were used, an adjustable shunt was made for each transformer and the combination calibrated with a particular element for a range of 3000 to 30000 amperes. After the instrument was mounted at the scene of tests, it was necessary to adjust the spring tension in each element so that upon passing a certain current through the shunt the same deflection was obtained as on the calibration with the same field strength. The same applies to the voltage elements except that the resistance was placed in series instead of in parallel with the elements. The accuracy of the oscillographic records was therefore insured.

A wiring diagram of the complete testing outfit, as used during tests, is shown in Fig. 3. All control leads from the circuit breakers were kept in the clear from the high-tension leads and were drawn through a thoroughly grounded pipe to the control panel. The circuit breaker frames and transformer cases were all solidly grounded. In tests of this nature too great care cannot be given to such matters as grounding all parts with which an opera-

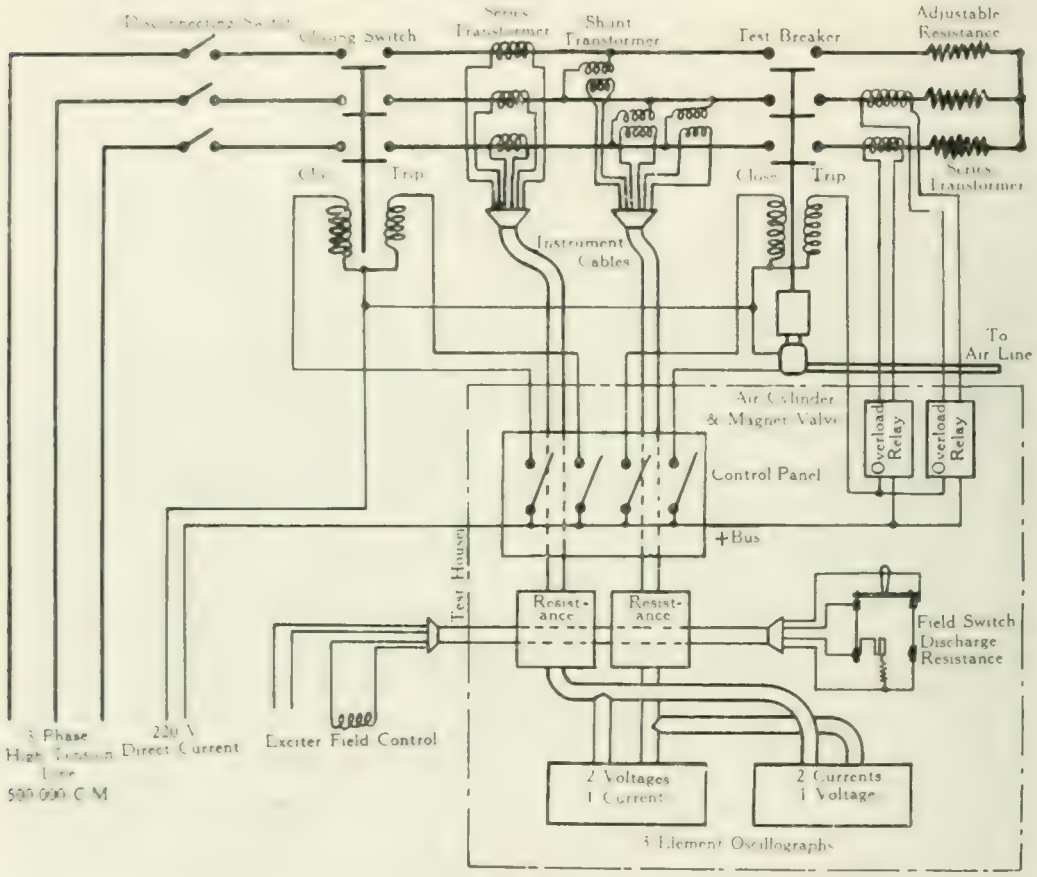


FIG. 3.—SCHEMATIC DIAGRAM OF CONNECTIONS FOR CIRCUIT BREAKER TEST

In some of the tests the shunt transformers were connected across the circuit breaker terminals instead of as shown.

tor may come in contact while the voltage is on, or to which an arc may flash due to some unexpected failure.

TEST CREW

In making tests of so extensive a nature it is necessary that the test crew be thoroughly organized and every man familiar with his duty. The most important member of the testing crew is the operator of the control board, who should be the leader during the test periods. A man was stationed at the governor of each ma-

chine. The switchboard operator was necessarily on the alert so as to be in a position to cut apart from the load any machine that might drop out of synchronism. The operators of the oscillographs are necessarily experts in their line. On these tests a record of 125 perfect oscillographs out of a possible 130 was made.

It was the duty of the remainder of the crew to change connections, assist in inspection and perform the labor necessary for setting up the various combinations. Cable crews were used on cable tests, handling the cables at the far end and making the short-circuits by means of the short-circuiting device shown in Fig. 4. This device consisted of a treated wood frame on each side of which were fastened permanently a plate and one phase of a three-phase cable. The third phase of the cable was securely fastened to the pivoted arm which, when its support was removed fell across the other two phases, making a simultaneous three-phase short-circuit. The cord shown at the left is for the purpose of operating the oscillograph shutter switch closing the circuit through a local telephone line, which was temporarily used for this purpose.

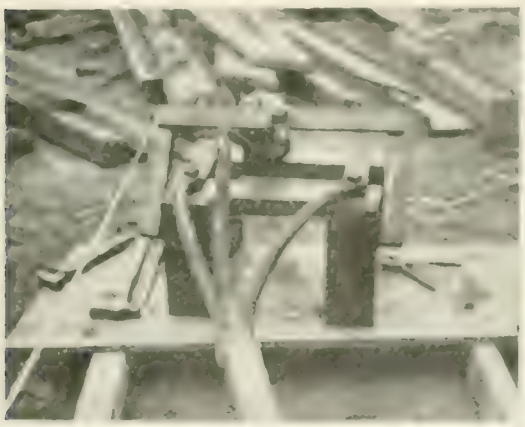


FIG. 4.—ARRANGEMENT FOR SHORT-CIRCUITING THREE-PHASE CABLE ENDS

A photographer was among the witnesses in order to obtain photographic records of the disturbances. In most cases, however, the effects were of such short duration and so little visible effect accompanied them that practically no disturbance was visible on the films.

SEQUENCE OF OPERATION DURING TEST

On direct short-circuit tests the following events take place in the order named, referring to Fig. 3:—The disconnecting switches are closed, the test circuit breaker is closed and the oscillograph operators start their arc lamps and motor, notifying the control operator when ready for the test. The control operator pulls a whistle cord warning the entire crew that the short-circuit will be thrown on in fifteen seconds. The oscillograph operators remove the slides on the film holders. Thirteen seconds after the first whistle a second whistle is blown to inform all that the cir-

ing switch is to be closed at once. When the test circuit breaker has opened the closing switch is opened. Then the disconnecting switches are opened and inspection and records made as are desired.

When making cable short-circuits at the far end of the cables the watches of both sections of the crew were timed alike over the telephone and arrangements made that at a certain time the cable would be made alive, and a definite period afterwards the short-circuit device would make the connections. Otherwise the method is the same as described for direct short-circuits.

RECORDS OF TESTS

A few of the records are shown as a means of illustrating the results obtainable in high power circuit breaker tests. The short-circuit characteristic on the particular type of generators tested is shown in Fig. 5. The curve is made up from the average of the three-phase currents. The effect of time element relays and of delayed circuit breaker action are evident. The long time element has the advantage of limiting the shock, at the time of opening, on circuit breaker apparatus situated close to large generating capacity. It has however, a number of disadvantages. The voltage of the system drops to a low value for so long a time that synchronous apparatus on the system may drop out. Another is the destruction that may be caused at the point of short-circuit or in the wiring leading thereto.

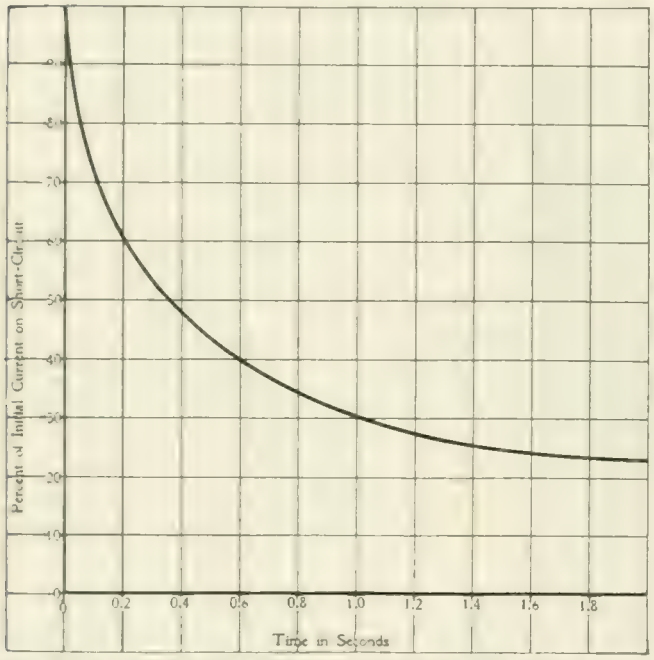


FIG. 5—LOAD-TIME CHARACTERISTICS ON PROLONGED SHORT-CIRCUIT
Hydraulic Power Company's Generators.

The advantage of quick opening is in reducing the extensiveness of destruction and disturbance in apparatus beyond the circuit breaker. The disadvantage of quick opening is in the high voltage shocks that may be imposed on the system on causing the energy flow to cease while at a maximum. In the case of the

generators the curves and oscillograms show that the maximum current occurs on the first few waves of the short-circuit before any practical circuit breaker could operate. It is evident that quick action on the part of the circuit breaker would not eliminate the mechanical and magnetic shocks in the windings and structure of the generators.

To open the short-circuit during this maximum condition of current flow and the resulting high magnetic flux causes extreme rise of voltage in the generator windings which are influenced by the sudden change in magnetic flux. The great amount of stored energy in the structure of the generator must be absorbed in some manner and it is preferable to reduce this to a considerably smaller value by permitting the short-circuit to persist for a number of cycles. In practice a non-inductive load in shunt to the gen-

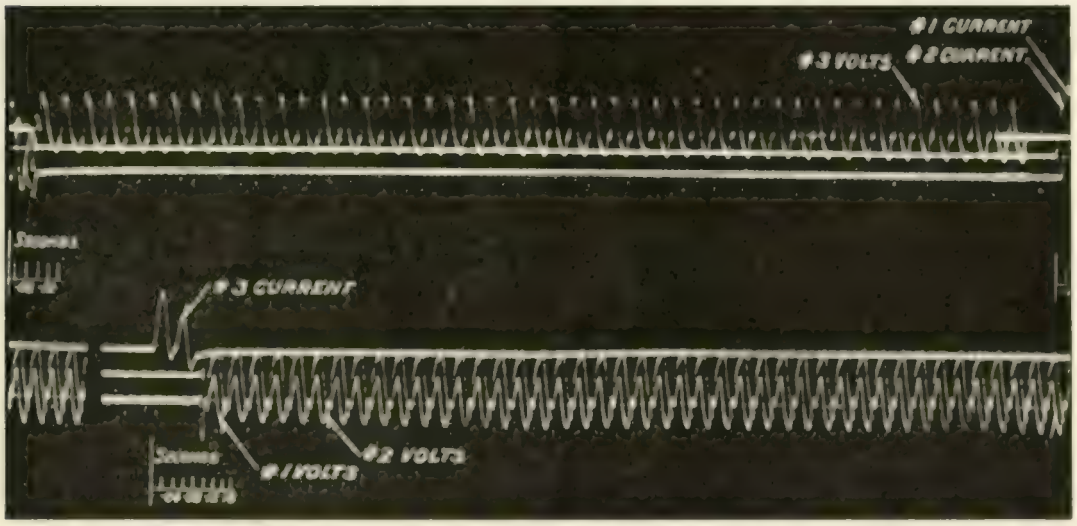


FIG. 6—OSCILLOGRAPHIC RECORD OF OPERATION OF QUICK ACTING CIRCUIT BREAKER OPENING DIRECT SHORT-CIRCUIT

In this and the following oscillograms the photographic film was wrapped around a rotating drum and the exposure was made during one complete revolution, starting at any desired instant, but not at any particular portion of the film. The record should, therefore, be considered as the development of a cylinder in which the beginning of the record does not necessarily coincide with the edge of the film. For purposes of reference it should be kept in mind that the time scales on the upper and lower records are simultaneous, although taken on separate oscillographs.

erator bus-bars could be provided to absorb this energy. It is rarely possible in practice to get a commercial load of this character on a circuit sufficiently short to be of low impedence. Several such loads would be necessary in order that at least one would be on the bus-bars while disturbances are being cleared in one or a number of the other circuits.

Quick and positive action of the operating mechanism is one of the most important features of successful circuit breaker ac-

tion. The improved types of circuit breakers tested at Niagara Falls showed this characteristic to an unusual degree, as indicated in Fig. 6, which is the oscillographic record of currents and voltages when opening a direct short-circuit on the bus-bars. From the time scale it is noted that the circuit was opened in less than 0.00 second from the time the circuit was closed, this being undoubtedly the most speedy circuit breaking ever recorded on like capacity and voltage. This remarkably short time element was obtained by using self-contained series transformers connected directly to the trip mechanism. This quick action increases the difficulty of breaking the circuit, as will be noted from Figs. 5 and 6, showing that the circuit breaker was compelled to open the circuit

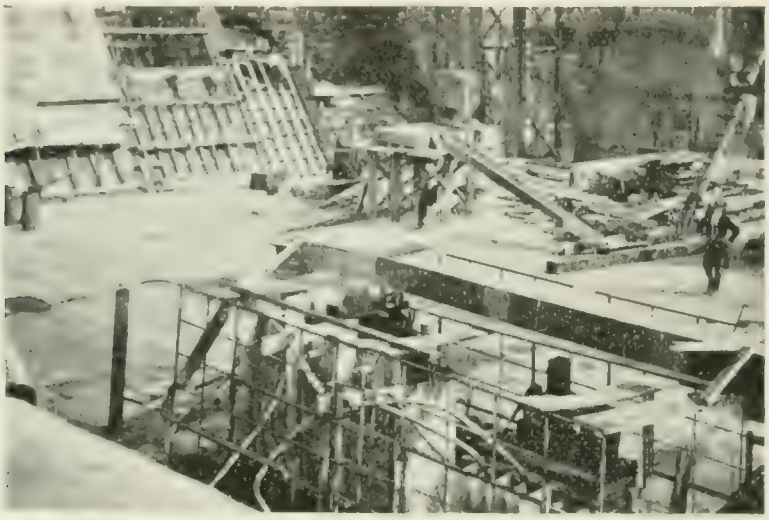


FIG. 7—VIEW OF TEST CIRCUIT BREAKERS TAKEN AT THE TIME OF THE SHORT-CIRCUIT TEST RECORDED IN FIG. 6.

while the current values and the voltage rise were practically the maximum. It will also be noted that the resulting voltage rise is excessive when short-circuits are cleared so rapidly under these conditions and greater damage to the generating apparatus may result from this cause than from the action of this form of circuit breaker when tripped later and the current broken further along on the short-circuit characteristic of the machine. The condition of this test was a direct short-circuit at the circuit breaker in shunt to the generator bus with a full load of electric furnaces supplied through several underground cables of low inductive reactance in parallel. This form of load and circuit would naturally tend to absorb the energy kick from the generator when the short-circuit on the bus-bars was cleared. It was found in subsequent tests

with this type of circuit breaker, operated as in the test above but with the generators isolated from all load other than the short-circuit, that the voltage rise was sufficient to break down the insul-

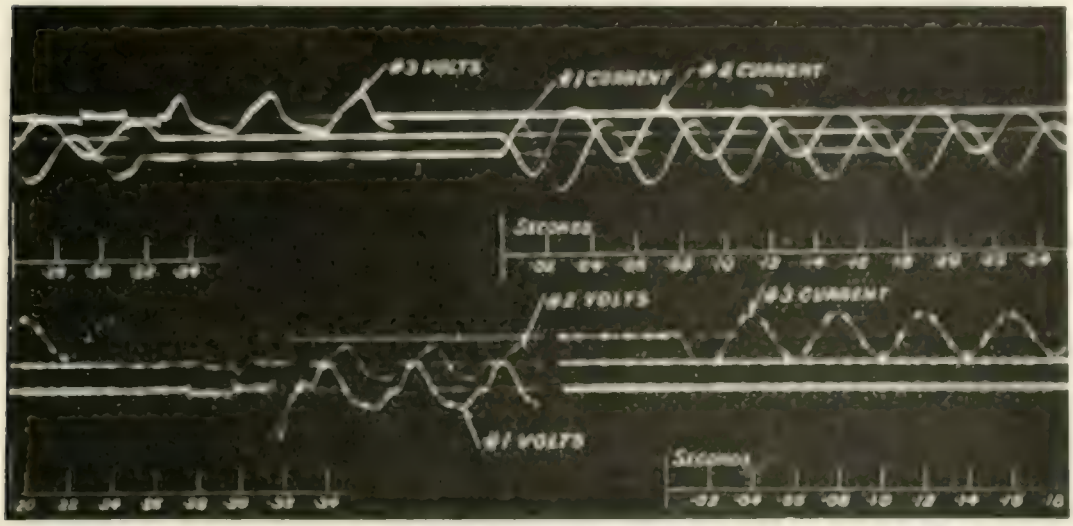


FIG. 8—OSCILLOGRAPHIC RECORD OF THE OPERATION OF A CIRCUIT BREAKER OPENING A SHORT-CIRCUIT

The voltage rise across the circuit breaker contacts is indicated. The circuit was opened in one and one-half cycles. The generators were cut off from load during the test.

ation of the generators. The absence of any spectacular effects accompanying this test is shown by Fig. 7.

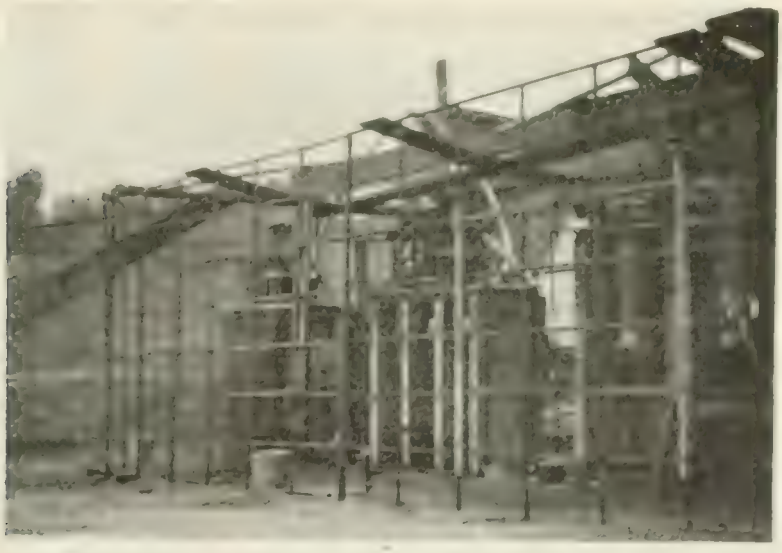


FIG. 9—VIEW OF CIRCUIT BREAKER TAKEN AT THE TIME OF OPENING A HEAVY SHORT-CIRCUIT AS RECORDED IN FIG. 8

Fig. 8 shows the oscillograms and Fig. 9 the visible effects accompanying a heavy short-circuit on machines on separate bus-bars isolated from load. The oscillograms show good circuit

breaker action and high voltage rise at the instant of breaking, due to the discharge of the magnetic field in the iron structures of the generators. The voltage waves are across the contacts of the test breaker. This test was made with trip transformers used in con-

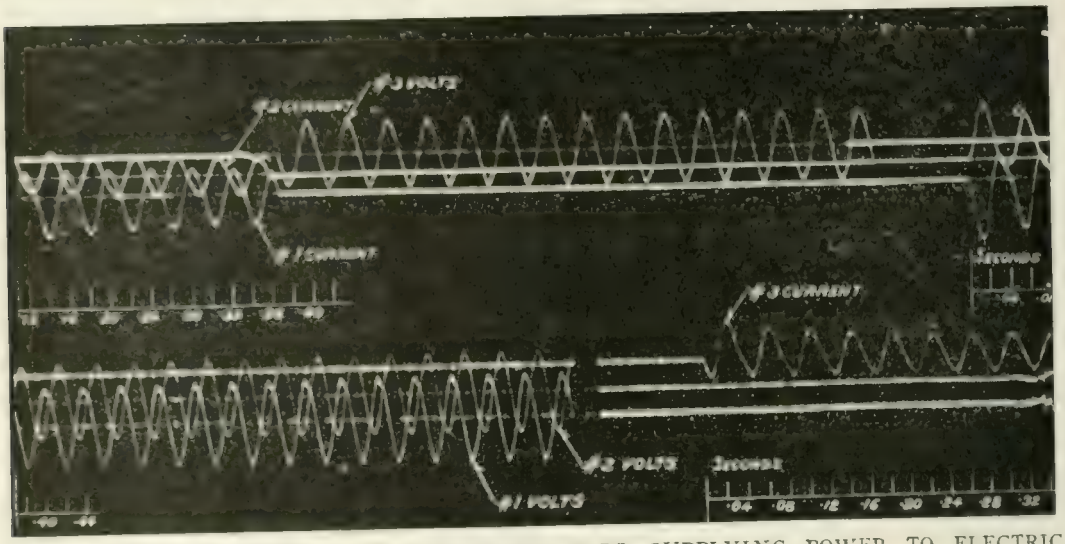


FIG. 10—RECORD OF A TEST WITH GENERATORS SUPPLYING POWER TO ELECTRIC FURNACES

nection with instantaneous relays and direct-current trip coil, all of which delay the opening of the breaker after the short-circuit is thrown on. The circuit breaking was performed in one to one and a half cycles on the different phases, whereas the short-circuit was on for seven and a half to eight cycles.

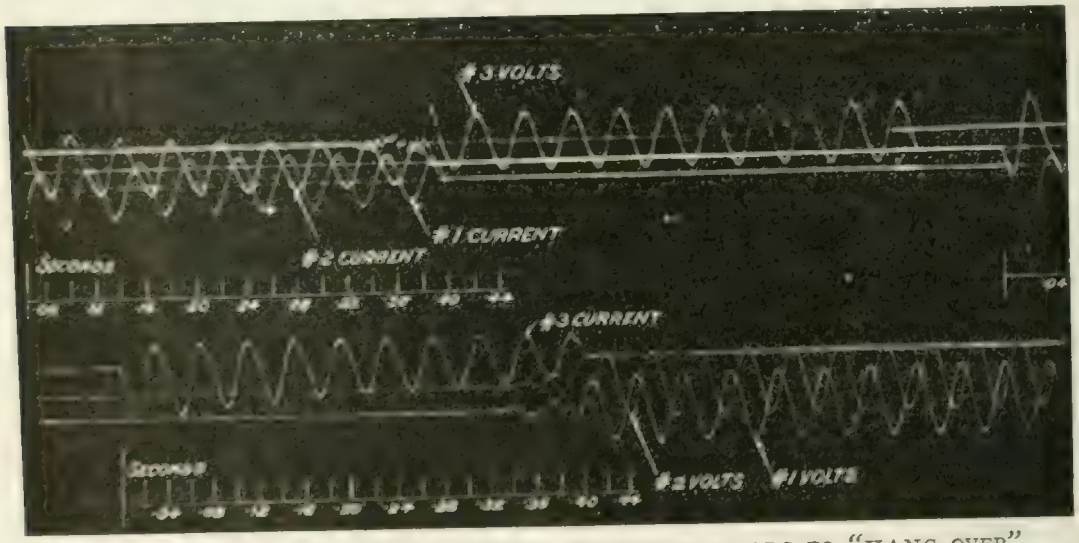


FIG. 11—RECORD OF A TEST SHOWING TENDENCY OF ARC TO "HANG OVER"

The oscillograms of a test which is directly comparable with that shown in Fig. 8, are given in Fig. 10, the difference between the two tests being that the first is on machines on un-

loaded bus-bars while the latter is on the bus-bars of machines feeding an electric furnace load. Voltage is delta voltage on machine side of test breaker. Oscillograms are given in Fig. 11 of a test which shows the voltage conditions that are often met with

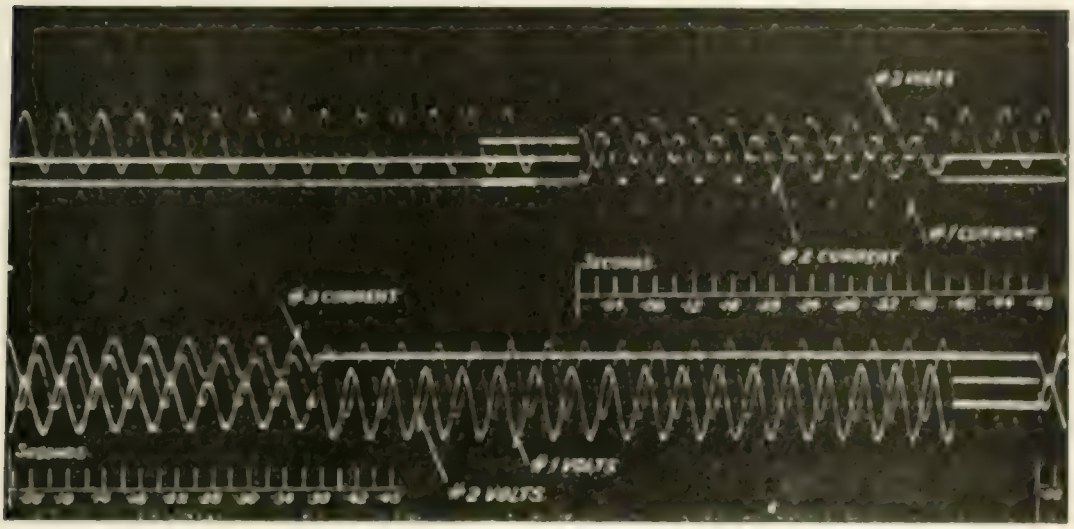


FIG. 12—RECORD OF A TEST TAKEN WHEN OPENING A HEAVY CABLE SHORT-CIRCUIT

on a high current arc in oil, tending to either maintain or re-establish the arc. The voltage indicated is the delta voltage on the machine side of the circuit breaker.

The oscillograms of Fig. 12 cover a test indicating excellent circuit breaker action when opening a heavy cable short-circuit.

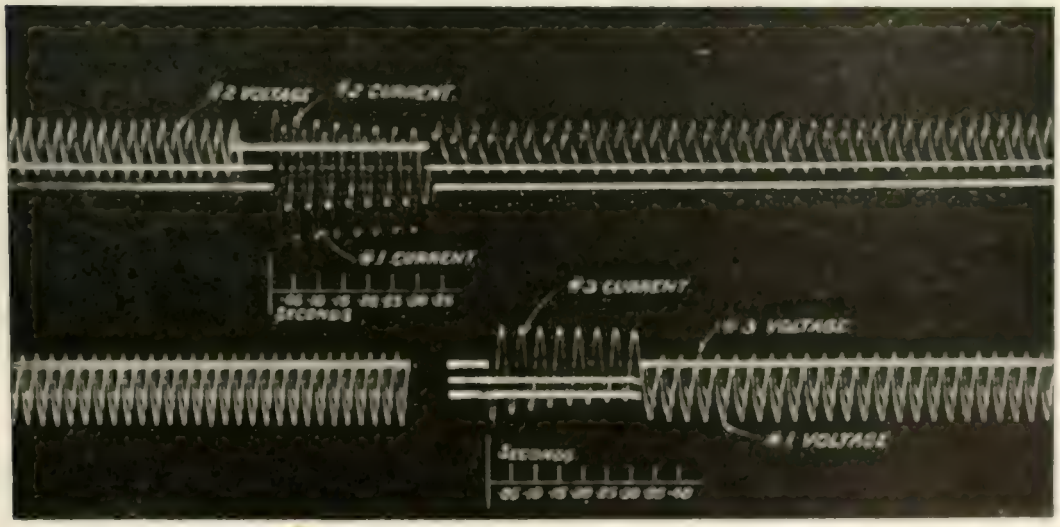


FIG. 13—RECORD OF SHORT-CIRCUIT TEST ON IMPROVED TYPE CIRCUIT BREAKER

The high voltage surges at the instant of breaking may be noted. This cable short-circuit consisted of closing on a fused short-circuit, using as a fuse one No. 36 copper wire wound on three inch

copper per phase. The presence of harmonics expected in an arc short-circuit was not shown by the oscillograms. The voltage waves indicate delta voltage on the cable side of the breaker.

A test taken on an improved type of circuit breaker with standard mechanism is shown in the oscillographic records of Fig. 13 and the pressure indicator card of Fig. 14. These records show perfect operation of the breaker; but a few drops of oil were ejected and but little smoke was emitted. The oscillograms are somewhat crowded owing to the low speed of the oscillographs. Better proportions are shown in the oscillograms of Fig. 15 and in the indicator card of Fig. 16; both were taken on a test which was a duplicate test to that shown in Fig. 13, but with a different tripping condition. The oscillograms, when compared, show the difference between quick acting and slow acting relay settings.



FIG. 14—PRESSURE CARD
On medium stroke oil circuit breaker, taken in air chamber above oil.

Records of a test on a quick acting type of circuit breaker

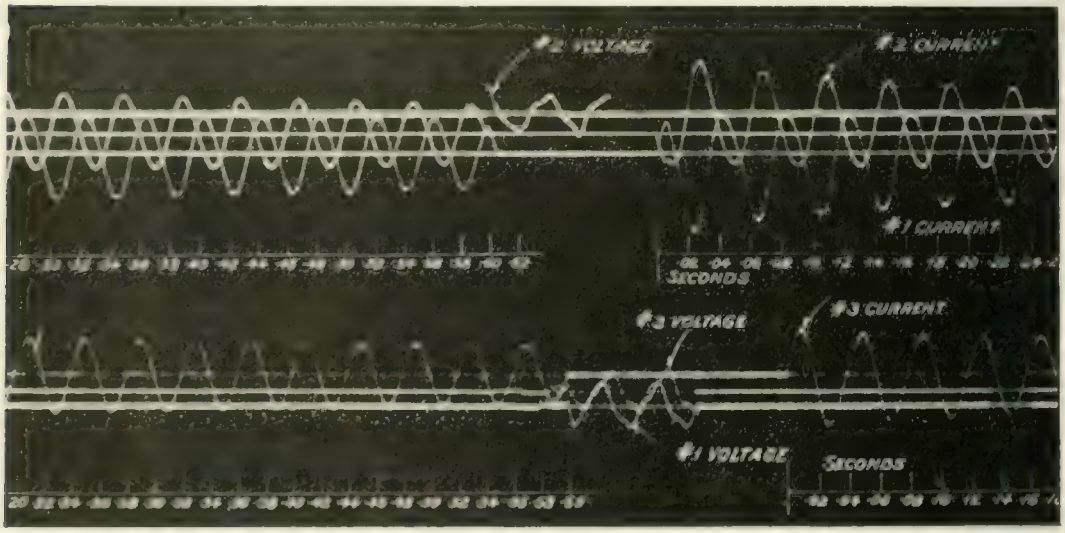


FIG. 15—RECORD OF TEST SIMILAR TO THAT IN FIG. 13, BUT WITH DIFFERENT TRIPPING CONDITIONS

opening a direct short-circuit on part of a cable system are shown in Figs. 17, 18, and 19. Fig. 17 shows the oscillograms, Fig. 18 the pressure indicator card, and Fig. 19 a photograph. There was practically no external demonstration except slight smoke from the circuit breaker vents. This test is comparable with that shown in

Fig. 6, the only difference being that a live, unloaded cable system on loaded bus-bars is involved in the test given in Fig. 17. The short-circuit was closed on a cable with the system alive to full voltage and the cables fully charged. The time required to open the cable short-circuit was approximately 0.16 seconds while the time required to open the direct short-circuit was approximately 0.09 seconds. The records show that the effect of a cable system is to produce a more tenacious arc, due to the dielectric capacity of the cable in addition to the magnetic energy in the rest of the system. The voltage waves indicated are those across the circuit breaker contacts.



FIG. 16—[illegible] CARD
Corresponding to Fig. 15.

SUMMARY

For successful operation, a circuit breaker should have an operating mechanism giving quick and positive action. The tests

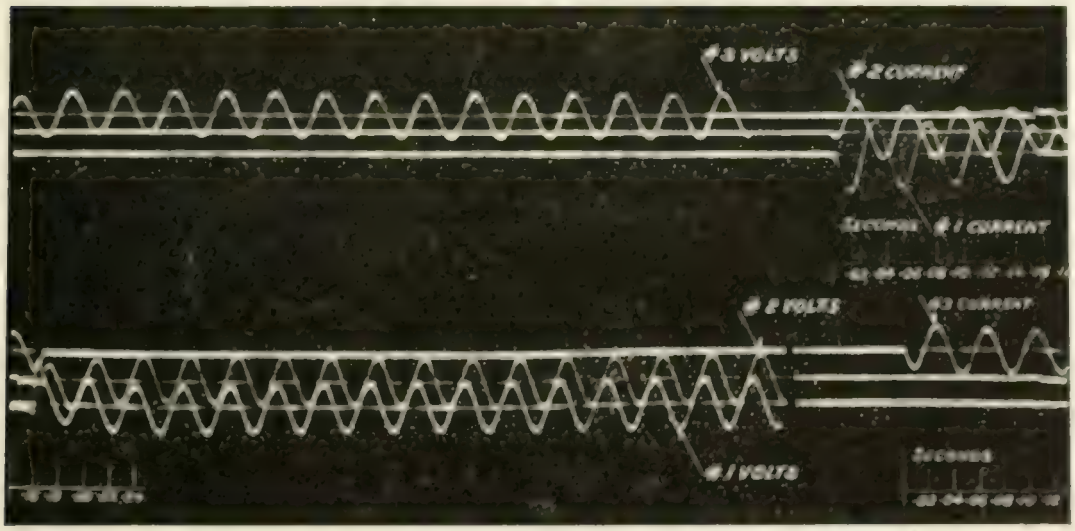


FIG. 17—RECORD OF A TEST ON IMPROVED TYPE OF CIRCUIT BREAKER
Opening short-circuit on cable system.

show that speeds of circuit breaker operation as low as 0.09 seconds have been obtained and that an average of 0.3 to 0.6 seconds is usual, depending on the method of tripping and the type of circuit breaker and instantaneous relay. They also show that the voltage disturbance increases with the speed of operation. Iso-

lated generators present, on a given short-circuit, a harder circuit breaking problem than a like short-circuit from bus-bars which also carry another load. The nature of this load is also a large factor.

While a long time element serves to limit the shock to the circuit breaker when opening circuits with large power and low impedance involved, it allows of objectionable drop in voltage, and

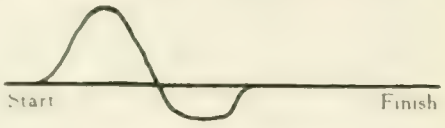


FIG. 18—PRESSURE CARD ON SHORT STROKE CIRCUIT BREAKER
Corresponding in Fig. 17. Taken near the arc in oil vessel.

of extensive destruction at the point of short-circuit. On the other hand, it is not only impracticable but undesirable to interrupt a short-circuit during the first cycle when the current is at a maximum. The shock to the generator is not eliminated by any



FIG. 19—VIEW OF CIRCUIT BREAKER TAKEN AT TIME OF SHORT-CIRCUIT TEST RECORDED IN FIG. 17

practical speed of operating, and such interruption of the magnetic flux results in serious rise of voltage, unless some other suitable means of absorbing the accumulated energy is provided, a requirement difficult to meet successfully in commercial operation.

Moreover, under some conditions, oscillatory surges and resultant voltage rises, due to the combined effect of this accumulated generator energy, and the presence of cables make it difficult for the circuit breaker to operate satisfactorily. Hence, the stored dielectric and magnetic energy in the apparatus and lines of the system that affect a circuit breaker in a particular situation must be considered in selecting a circuit breaker of appropriate "ultimate capacity" or circuit breaking ability. This factor is independent of the insulation and current conducting characteristics of the circuit breaker.

The results of the tests demonstrated that high power circuit breaking apparatus is practicable and can be installed on large power systems with perfect confidence in its satisfactory operation under the most severe operating conditions.

The staff of the Hydraulic Power Company, Messrs. Harper, Lee, Gottlieb, Scott and Ross, deserve great credit for their assistance in conducting and making possible these tests, as a result of which exact operating conditions may be presented graphically for the benefit of the profession generally. Messrs. Funk and Armour, of the manufacturers' engineering staff, also deserve commendation for their valuable assistance in carrying the test program to a successful conclusion.

GATHERING BY ELECTRIC MINE LOCOMOTIVES

G. W. HAMILTON

THE results obtained in service by the use of gathering locomotives depend so much on the conditions to be met, that the consideration of details covering these conditions of operation in the mine, is of greatest importance. As all is based on the arrangement of the mine, certain questions should always receive investigation:—

1—From how many cross entries will the cars be gathered to secure the maximum output?

2—What will be the distance from the outside working room on each cross entry, to the parting on which loads will be placed for main haul locomotives, and from which empties will be secured for the rooms?

3—How many working rooms will there be in each cross entry? (From this information data regarding the average maximum output of the cross entry will be secured.)

4—How many loads may be counted on per day from each working room?

5—How many loads may be counted on per day from the face of each working cross, or main, entry?

6—How frequently does the main haulage locomotive visit the parting served by the gathering locomotive, and how many loads and empties does it respectively haul away and leave on each trip?

7—What is the average distance from the inside working room to the face of the cross entry on which it is located?

8—What is the average length of all the working rooms on each cross entry; and the maximum length of any working room to be served?

9—Will the gathering locomotive pull the load from, and set the empty at, the face of each working room, or will one of the cars be gotten from, or set at the face and the other picked up at the room neck inside the switch?

10—Where will the cars for the face of each cross entry be pulled from and set; at the face—just inside of the inside room switch—or inside of the open crosscut switch?

11—If rooms are driven from one cross entry only, of each pair, will the gathering locomotive have to set the empty at the face of the back entry as well as pull load, or where may the empty car for the back entry be left?

12—What will best suit the conditions; to gather loads and set empties in the same entry; or to gather loads from one entry, and set empties in the other, and vice versa?

13—What kind of track will be laid in working rooms; 2 in. by 4 in., or 3 in. by 4 in. wooden lagging, rails without fishplates, or rails with fishplates? Obtain details of track.

14—What kind of switch has been, or will be laid into each room and crosscut; stub point, single latch and stub point, double latch operated separately, or double latch tied together?

15—What is the radius of sharpest curves into rooms, and from main entries into cross entries?

16—Do all switches from rooms face out?

17—How much clearance is there, between rail and near rib, on curves into rooms?

18—What kind of coupling is used on cars, and what clearance does it give between cars, when coupled and stretched on straight track?

19—Where will the trolley wire be located in relation to the track on each cross entry, when facing out?

20—Gauge of track as laid; grades with direction and length, in cross entries and rooms; weight of empty cars, and of their loads; frictional resistance of empty cars; general dimensions of loaded cars; voltage, etc.

Having secured this information, and a good idea of the layout of the mine while obtaining it, the details which control the weight and capacity of the gathering locomotives will be found in the questions which follow:—

1—Maximum grade against, or in favor of, the loads on the cross entries?

2—Number of working rooms per entry with cars loaded per room?

3—Weight of rail in rooms, and on cross entries?

4—Average and maximum length of rooms and length of runs to partings?

5—Weight of loaded cars?

6—Clearance between rail and roof, and rail and rib?

The significance of these questions will be further evident from the following considerations:—

1—If the grades on the cross entries are severe they will limit the length of trip, unless a heavy locomotive be used, and this item is determined by the weight of track rail, general construction, and clearances.

2—If the grades and weight of rail do not limit the size of the locomotive, the length of trip will depend on the number of rooms to be served, the frequency of the service, and the length of the runs, all of which tend to determine this feature.

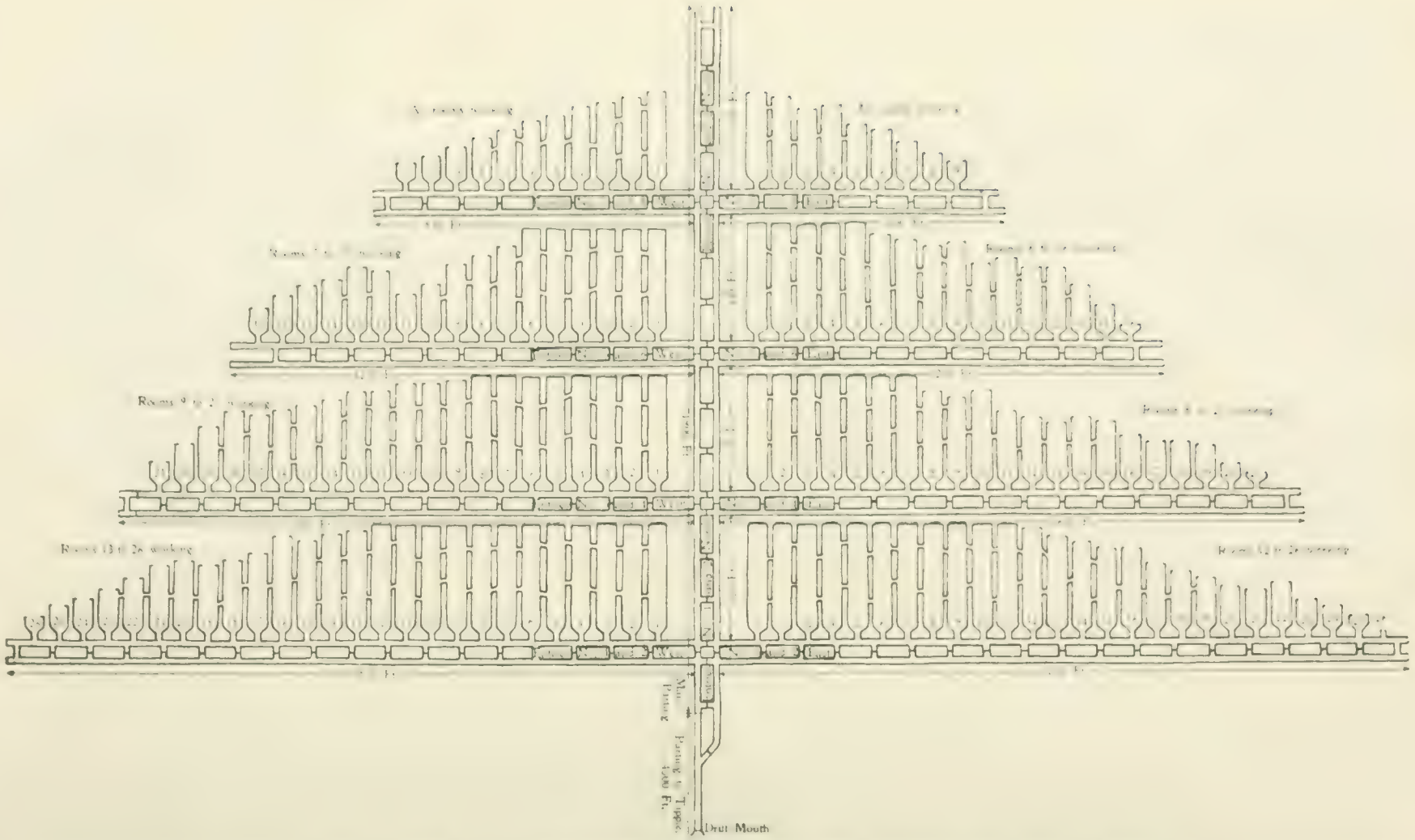


FIG. 1—PLAN OF WORKINGS OF A PENNSYLVANIA BITUMINOUS COAL MINE
Showing entries and rooms. The course of the ventilating air in the entries can readily be traced. Original scale, 200 feet to the inch.

It must also be remembered, that satisfactory service is equal service to all, and if five cars are set and hauled in a certain room, the same must be done in all other working rooms cared for. The service therefore becomes a question of time distribution more than all else. A typical proposition has been worked out below, the data being taken from the note book of the engineer making the preliminary survey, and being accompanied by a sketch such as that of Fig. 1, showing the general plan of the workings to be developed.

Data secured:—

1—Gauge of track—42 inches, laid 41 ½ in. to 42 ½ in.

2—Weight of rail—20 lbs. per yard on cross entries, 3 in. by 4 in. lagging and 16 lb. iron in rooms. (Lagging will be replaced by iron).

3—Radius of curves—about 20 ft. into rooms and 25 ft. into main entry from cross entries.

4—Weight of empty car 1600 lbs.

5—Weight of load in car, 3600 lbs.

6—Frictional resistance of empty cars, 22 lbs. to 24 lbs. per ton.

7—Maximum grade against the loads for 400 ft. on cross entries to the west, 3%. Maximum grade in favor of loads for 500 ft. on cross entries to the east, 3%. Maximum grade in favor of loads on main entries and in rooms, 1% or level.

8—Number of entries to be served—8 (four to the east and four to the west).

9—Maximum length of run from rooms to parting about 2000 ft.

10—Maximum number of working rooms on any cross entry, 12; average, 10.

11—Maximum number of cars per room loaded each working day, 6.

12—Maximum number of cars loaded (in pairs) at each entry face per day, 12.

13—Parting is served by main locomotive, 24 times per day, with from 30 to 35 cars per trip.

14—Average distance from inside room to face of cross entry, about 70 ft.

15—Maximum length of working rooms, 300 ft.; average length of 12 rooms, about 150 ft. each.

16—Gathering locomotives to set empties inside of room switch, and haul loads from face of rooms.

17—Cars to be placed at face of all cross entries.

18—All room switches face out.

19—Clearance between rail and near rib, about 2 ft. minimum.
20—A passing track will be laid in each cross entry, outside of working rooms, or about 1000 ft. from the face.
21—Rooms will be equipped with good double latch switches cross-strapped together.
22—Double link and pin coupling between cars which have single bumpers. Distance between bumpers when cars are being hauled, 3½ inches.
23—Height over car topping, 48 in. Length over bumpers, 9 ft.
24—Trolley will be located on cross cut side of entries; from about 0 in. to 6 in. outside of rail, and 4 ft. to 5½ ft. above the rail.
25—Minimum clearance between rail and roof, 4 ft. 6 in.
26—Output wanted, 1300 tons in 10 hours.
27—Voltage, 250 volts, direct current.

With 16 lb. iron for the track in the rooms the gathering locomotive should not weigh over six tons, and if the maximum trips required, viz., twelve cars, are hauled from the rooms, and two cars from the face of each cross entry, i. e., a total of sixteen, the drawbar pull on a three percent grade will amount to 3494 lbs. and the tractive effort with a six ton locomotive will be 3974 lbs. To develop this tractive effort will call for about 33 percent adhesion and there is no doubt a locomotive of this weight will take care of the load as required. When the average maximum trip of 14 cars is considered, the tractive effort falls to 3537 lbs. on the three percent grade, which requires less than 30 percent adhesion.

The working schedule will be approximately as follows:—

First Round Trip Into Second Cross Entry, East;

From the main parting to the passing track with 16 empties, a distance of about 1 200 ft. at maximum, the running time, approximately	2 minutes
Gathering 4 loads from faces of second and first east entries, the distance from passing track being 1 000 ft.	4 minutes
Gathering 12 loads from faces of 12 rooms and placing total of 16 loads on passing track	20 minutes
Setting 12 empties inside of 12 room switches, and 4 empties at faces of entries	13 minutes
Running with 16 loads to main parting	3 minutes
Time spent at main parting	5 minutes
Total time per round trip	47 minutes

The schedules into the fourth and sixth cross entries east, and into the second, fourth and sixth cross entries west, will be practically as above; but when the run is made into the eighth east and the eighth west, an extra four or five minutes must be allowed for placing two empties at, and pulling two loads from, the face of

No. 1 or No. 2 north, and this work must be done before taking the rest of the trip into either cross entry. In other words the gathering locomotive will leave the parting and return with 18 cars, 16 of which are gathered from one of the cross entries, and two from the face of one of the main entries.

The schedules, under maximum conditions, from the several entries will be as follows:—

From the Second, Fourth and Sixth Cross Entries, East and West:

Six round trips at 47 minutes each, or 282 minutes per entry

From the Eighth, East and West, and the First and Second North Entries;

Six round trips at 51 minutes each, or 306 minutes per entry.

Total time under maximum conditions for the second and fourth, east and west, 564 minutes for each pair.

Total time under maximum conditions for the sixth and eighth, east and west, 588 minutes for each pair.

Maximum number of cars per locomotive per day, 198.

Number of gathering locomotives required, 4.

Maximum output secured, 1 425 tons.

The schedule outlined assumes the length of run into each entry as 2000 feet at a maximum, and the cars to be hauled each trip as from 16 to 18, i. e., the maximum number. It also assumes that on starting out in the morning a loaded car will be waiting in each room and that the first trip into each entry will be complete; which will seldom, if ever, be the case. Under actual conditions, the length of each run, while it may reach 2000 feet in the second east and second west entries, wil not average over 1200 feet in the other entries, and if the first trip is secured during the first hour of the day, a good run may be expected. It is evident, however, that should the cars be supplied, and the tracks kept in a fair condition, the locomotives outlined will gather the maximum output called for, namely 1300 tons, on time.

THE DETERMINATION OF THE POWER-FACTOR OF A THREE-PHASE CIRCUIT

BY MEANS OF TWO SINGLE-PHASE WATTHOUR METERS

HARRY N. LUCAS

THE power-factor of a balanced three-phase circuit at any time can be determined by the use of two single-phase watthour meters from the ratio of the revolutions of their respective discs; or the hourly power-factor from the ratio of the hourly readings; and the daily average power-factor can be determined from the ratio of the daily meter readings. If a polyphase watthour meter is used the power-factor can be determined if the load is approximately constant, from the ratio of the number of disc revolutions in a given time as obtained by separtely disconnecting each set of potential wires. Fig. 1 represents the meter connections. In Fig. 2,* I_{AB} represents the current in phase with

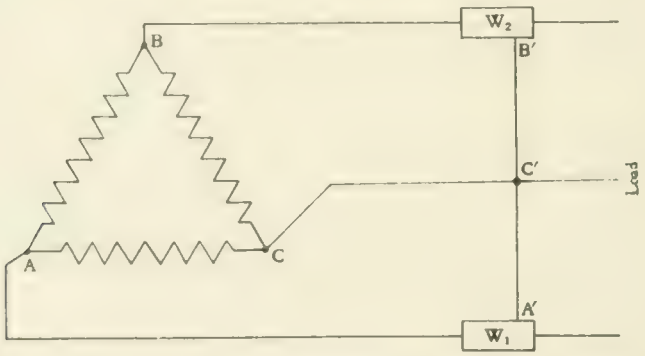


FIG. 1—METER CONNECTIONS FOR MEASURING THREE-PHASE POWER WITH TWO SINGLE-PHASE WATTHOUR METERS

the voltage E_{AB}; I_{CB} the current in phase with the voltage E_{CB}, and I_{CA} the current in phase with the voltage E_{CA}; all at unity power-factor.

The resultant current of I_{AB} and I_{CB} is represented by the line $I_{BB'}$ which, at unity power-factor of the load, lags 30 degrees behind the voltage E_{CB} or $E_{B'C}$ which are identical, except for line drop which may be neglected. The power registered by this meter W_2 (Fig. 1) is then equal to the voltage multiplied by that part of the current in phase with the voltage or $E_{B'C} \times I_{BB'} \times$

*The writer has used the same symbols, etc., as contained in the article by Mr. Chas. H. Porter, in the JOURNAL for September, 1907, and by Mr. M. H. Rodda in the JOURNAL for July, 1907.

cos 30°. In a similar manner, the resultant current of I_{BA} and I_{CA} is I_{AA}, which leads the voltage E_{AC} by 30 degrees. The power registered by meter W'_1 (Fig. 1) is, therefore, at unity power factor, also equal to the voltage multiplied by that part of the current in phase with the voltage, or $E_{AC} \times I_{AA} \times \cos 30°$.



FIG. 2—RELATION OF CURRENTS AND VOLTAGES WITH LOAD CURRENT IN PHASE WITH ITS VOLTAGE

The readings of the two meters, with balanced currents and voltages, are the same, giving a ratio of 1.

In Fig. 3 the vectors have been drawn to show a current lag of 30 degrees. In this case it will be noted that the normal lag of current in meter W'_1 and the lag of the load have been added,

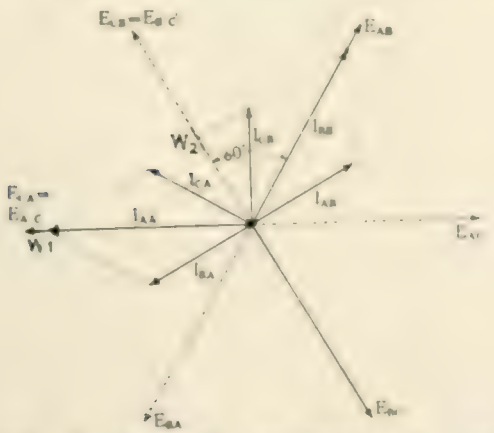


FIG. 3—RELATION OF CURRENTS AND VOLTAGES WITH LOAD CURRENT LAGGING BEHIND ITS VOLTAGE 30 DEGREES

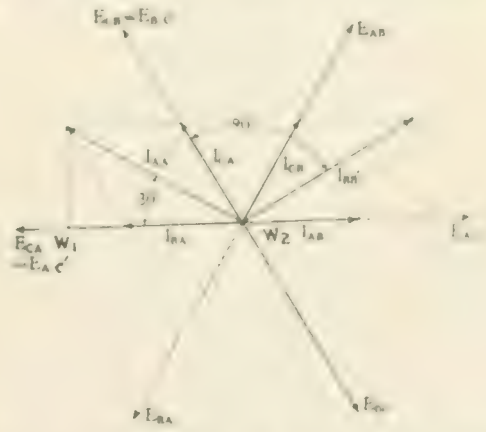


FIG. 4—RELATION OF CURRENTS AND VOLTAGES WITH LOAD CURRENT LAGGING BEHIND ITS VOLTAGE 60 DEGREES

causing the current I_{BA} to lag behind voltage E_{BC} by 60 degrees. The registration in this case is $E_{BC} \times I_{BA} \times \cos 60°$. Likewise the normal leading current of meter W'_2 has been counter-balanced by the lagging current of the load, causing I_{AA} to be exactly in phase with the voltage E_{AC}, so that the power registered is equal

to $E_{A'C'} \times I_{AA'}$, which is the maximum obtainable. With an angle of lag greater than 30 degrees, the current in meter W_1 lags behind the voltage. The ratio of the two readings with the relations shown in Fig. 3 is 0.5.

The vector diagram of Fig. 4 represents the case of a load of 60 degrees lag or a power-factor of 50 percent. The power registered by meter W_2 is equal to $E_{B'C'} \times I_{BB'} \times \cos 90°$, which is zero, or no registration. With a further increase of lag the registration of the meter is negative, and when determining the total power consumed should be subtracted from the registration of the positive reading meter. The registration of the positive

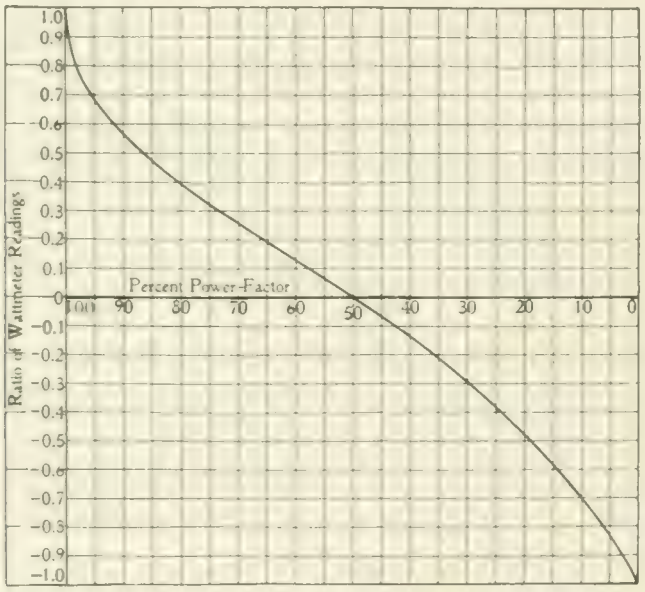


FIG. 5—DIAGRAM SHOWING POWER-FACTOR WITH ANY GIVEN RATIOS OF METER READINGS

reading meter is represented by $E_{A'C'} \times I_{AA'} \times \cos 30°$. The ratio of the meter readings is zero.

Vector diagrams can be drawn with any desired angle of lag or lead in the main circuit from which it is possible to determine the ratio of the ratings of the two meters for any angle. Inspection of the vector diagrams shows that the formula for the power registered by the low reading wattmeter equals E × I × cos (angle of lag + 30 degrees), while the power registered by the high reading wattmeter equals E × I × cos (angle of lag − 30 degrees. The ratios of these values have been plotted in Fig. 5. For power-factors lower than 50 percent the low reading meter rotates backwards and the ratio of readings is negative as shown in Fig. 5.

A STUDY OF THREE-PHASE WATTMETER CONNECTIONS

CHAS. R. RIKER

[In an article by Mr. H. N. Lucas in the present issue, vector diagrams are presented giving the relation between the line current and voltage in each of two meters used for measuring three-phase power, at different power-factors. It is believed that the accompanying curves, which have been drawn from data compiled by analysis of similar vector diagrams, will be of considerable value to meter testers and students in understanding the relations between the current and voltage in such meters whether correctly or incorrectly connected. Owing to the simplicity of this method of studying three-phase power measurements, it seems improbable that similar curves have not been worked out by others. The writer, however, does not remember having seen them published and they are presented in the hope that they may prove useful in assisting in the better understanding of the action of three-phase power measurements.]

A three-phase integrating watthour meter is electrically the same whether the two elements are mounted in one case as in a polyphase meter or whether they are mounted in two separate cases when two single-phase meters are used, and the connections to a three-phase line are exactly the same. The correct method for connecting two single-phase elements to measure three-phase power is shown in Fig. 1. Great care should be exercised in installing meters of this type to insure that the connections are made exactly in accordance with the proper diagrams. This is especially important in the case of meters for high voltages or large currents where either potential or current transformers are necessary, as, by a slight error in connections, excessive errors may be introduced, which are not readily apparent. It is not safe to assume that a three-phase meter is registering the correct load simply because the disc is rotating in the positive direction or because the disc rotates in the positive direction when either one of the shunt elements is open.

The term "wattmeter" is equally applicable in the present discussion to indicating wattmeters and to integrating watthour meters. Two single-phase meters are assumed, but the methods are equally applicable to polyphase meters in which readings on the individual elements can be taken consecutively under approximately similar conditions. All the diagrams and curves are based on an assumption of equal currents and voltages in the three phases, an assumption entirely warranted if three-phase motors only are included in the load. The term "correct reading" means correct only in so far

as the connection is concerned, and does not consider errors of calibration. The sum of the readings is of course the same whether it be the single indication of a polyphase meter or the algebraic sum of the readings of two single-phase meters.

The heavy curves in Fig. 2 indicate the correct readings of wattmeters, W_1 and W_2, together with the sum of these two readings, in terms of unit current and voltage, at all power-factors. It will be noted that the curve for the total power reading is a straight line, indicating that with unit current and voltage the power is in direct proportion to the power-factor. It will also be noted that when the power-factor becomes less than 50 percent the low reading wattmeter reverses and runs backwards for all power-factors below 50 percent.

A study of the curves in Fig. 2 will indicate that certain pre-

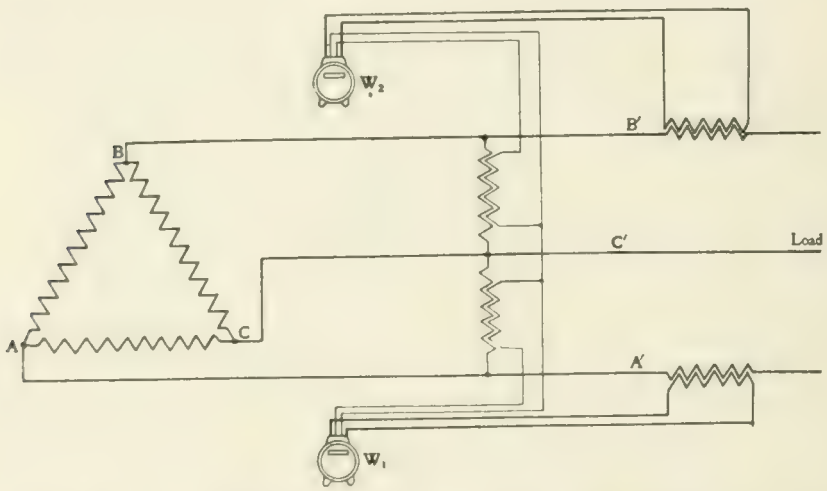


FIG. 1.—DIAGRAM OF CONNECTIONS FOR THREE-PHASE POWER MEASUREMENT
This is a general diagram. It can be simplified by leaving off either pair of transformers where they are not necessary.

cautions are necessary in connecting a polyphase meter as, owing to the fact that one element should normally reverse its direction of rotation on power-factors of less than 50 percent, it is not safe to depend upon the direction of rotation of each element to determine whether or not the meter is connected into the circuit properly, unless the power-factor is known. By connecting the meters, however, in a number of different ways and observing their actions, the correct connection can be determined.

There are a number of ways by which two single-phase wattmeters may be connected into a three-phase circuit, only one of which is correct. These are:

Case I—Correct—In which the current coils are connected into two separate phases and each of the shunt coils is connected from the phase of its current coil to the third phase as indicated in Fig. 1, each meter being so connected as to run forward at unity power-factor. The indications of each element and the total indication for this case are plotted in heavy lines in Fig. 2, as explained above. The curve for the total readings is a straight line whose ordinate is constantly equal to the sum of the ordinates of the curves for meters W_1 and W_2.

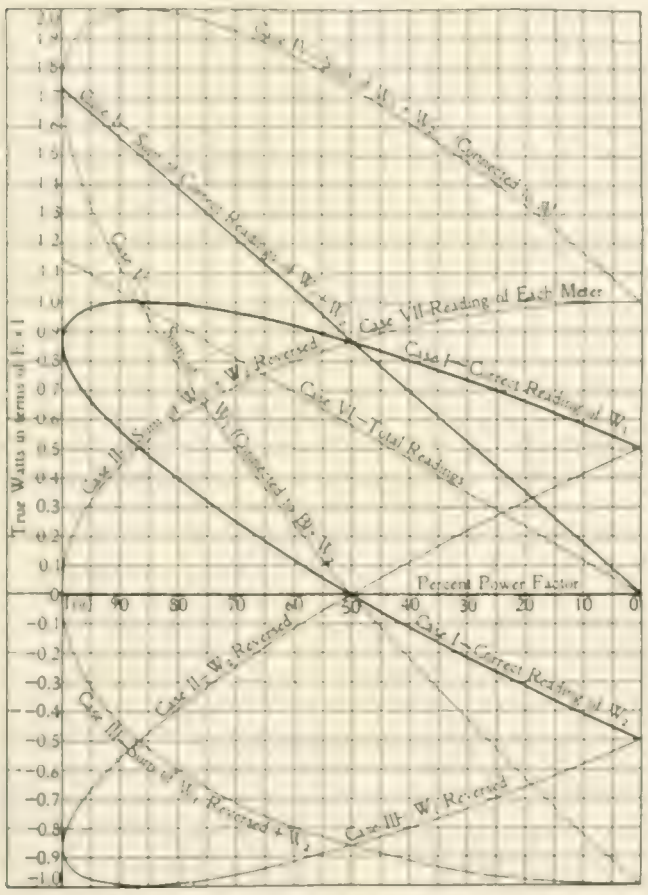


FIG. 2—READING OF WATTMETERS FOR ALL POWER-FACTORS WITH A VARIETY OF CORRECT AND INCORRECT CONNECTIONS

Case II—Incorrect—With W_1 properly connected and either the shunt coil or the current coil of meter W_2 reversed. It is evident that the sum of the readings of meters $W_1 + W_2$ with one coil reversed will give widely erroneous registration, being greater than the correct registration for power-factors below 50 percent and less for power-factors above 50 percent.

Case III—Incorrect—With either the shunt coil or the current coil of meter W_1 reversed, and W_2 properly connected. The sum of the readings of meter W_1 with one coil reversed plus W_2 properly connected will likewise give erroneous readings. As shown in Fig. 2 the sum of $W_1 - W_2$ in this case is exactly the same as in Case II but is negative.

Case IV—Incorrect—With W_1 properly connected and W_2 connected to phase A instead of phase C. Inspection of the vector diagram * will show that in this case instead of the current in meter

*See Fig. 2 of the article by Mr. Lucas, p. 763, of present issue.

W_2 lagging behind its voltage, it has a lead of 30 degrees. In other words, the readings of meters W_1 and W_2 will be the same at all power-factors, each giving the reading which is correct for W_1. As shown in Fig. 2 the sum of the two meter readings is in this case **excessive at all power-factors except unity.**

Case V—Incorrect—With W_1 connected to B instead of C and W_2 properly connected. From the vector diagram it may be seen that instead of the current in meter W_1 leading its voltage by 30 degrees it has a lag of 30 degrees. In other words, the readings of meters W_1 and W_2 will be the same at all power-factors each giving the reading which is correct for W_2. As shown in Fig. 2 the sum of the two meter readings is in this case much too low at **all power-factors except unity.**

Case VI—Incorrect—This condition is shown diagrammatically in Fig. 3, and is unusual in that, although the connections are in-

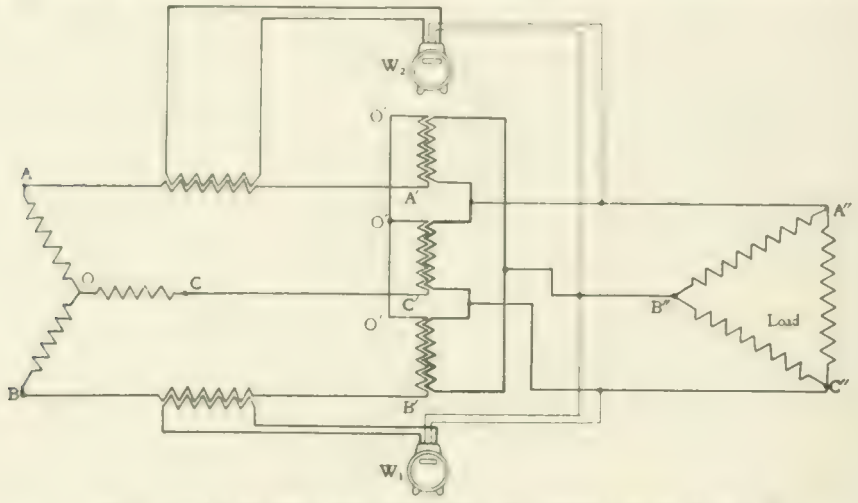


FIG. 3—IMPROPER CONNECTION ILLUSTRATING CASE VI

correct, the total reading, using a suitable multiplier, is correct under all conditions, except for errors introduced by magnetic leakage and voltage drop in the transformers. It is the condition arising with a star to delta transformation, with the current coils of the meter connected on the primary side of the transformers and the potential coils on the secondary side. It is evident that this will disturb the vector relations in both meters. The vector diagram, Fig. 4, shows, however, that at unity power-factor the current and voltage in each meter are exactly in phase and that for all power-factors of the load the power-factors of both meters will be the same and will be equal to the power-factor of the load, each meter measuring the power in one phase. As, however, the current and the voltage in the third phase are equal to the vector sum of the currents and voltages in the other two phases it is at

once evident that the total reading will equal two-thirds of the total power in the circuit under all conditions of load and power-factor, except for the slight error introduced by the transformers as mentioned above.

Case VII—Incorrect—The shunt coil W_1 connected across BC, and the shunt coil W_2 connected across AC. This condition is one which would be liable to arise only when voltage transformers are used and the leads are carried in a cable or conduit. It is peculiar in that the reading is in proportion to the sine of the angle of lag instead of the cosine. The readings of the two meters are equal at all power-factors and the reading of each meter is equal to the sum of the readings of the two meters in Case II.

It is evident that other incorrect connections are possible but the ones noted cover typical cases. Further errors caused by a reversed shunt or series coil in one meter are usually self-evident. For instance, in Cases IV, V, VI and VII if one meter is connected backwards the total reading will be zero and a polyphase meter will not run at all.

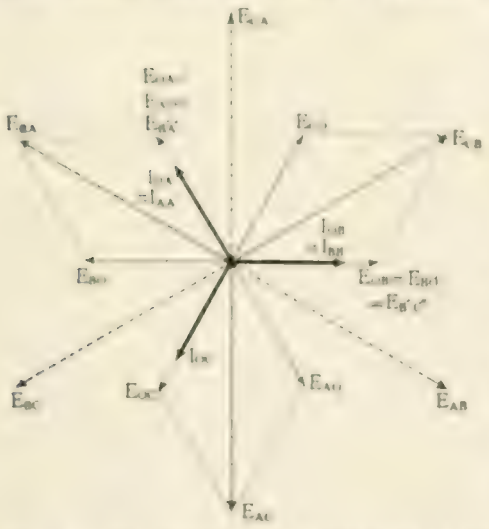


FIG. 4—RELATION OF CURRENTS AND VOLTAGES AT UNITY POWER FACTOR WITH CONNECTION SHOWN IN FIG. 3

For all the connections noted except Case VI it is safe to assume that the wattmeter is properly connected if both meters register in the forward direction for power-factors above 50 percent and one meter reverses for power-factors below 50 percent. When it is impossible to determine the power-factor by external conditions or when the leads from current and voltage transformers are brought through cable or conduit and cannot be distinguished the following tests may be made:

A—By testing with an incandescent lamp or voltmeter obtain three voltage leads having equal voltages between them, which can be called *A*, *B*, and *C*, and connect them to the voltage circuits of the wattmeters as per Fig. 5.

B—Connect the leads from the current transformers to the current coils of the meters in such a manner as to cause both meters to register in the forward direction.

C—At the transformers, before the leads enter the cable or conduit, short-circuit the secondary of one current transformer,* disconnect its leads from the cable and disconnect the corresponding potential transformer. If the current coil and the potential coil, which have been disconnected, are in the same meter, this meter will stop but the other will register. If the current coil of one meter and the potential coil of the other meter have been disconnected, both meters will stop. This is the condition assumed in Case VII and either the potential or the current leads of the two meters should be interchanged, and the connections re-established at the primary.

D—Change voltage connections of either meter from the third phase to that phase in which the other meter is connected. It must be remembered that the actual connections at this stage may or may not correspond with the diagram; the connections which have been assumed will, however, be considered correct until proven otherwise. At 100 percent power-factor the readings on this meter will be alike with both connections. If the power-factor is between 50 and 100 the readings will differ but will be in the same direction, *i. e.*, both positive. If the power-factor is equal to 50 percent the meter will stop with one connection while if it be less than 50 percent the meter will reverse in direction with one of the connections. By this test, it can be determined whether the power-factor is above or below 50 percent.

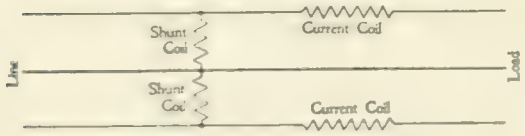


FIG. 5—DIAGRAM FOR PRELIMINARY CONNECTIONS

E—If the power-factor is below 50 percent, the meters should be connected so that the one which registers the least power registers backwards. If the power-factor is above 50 percent the meters should be connected so that both meters register forward but do not register the same amount of power unless the power-factor is exactly 100 percent. In case the tests under *D* indicate exactly 100 percent power-factor, *i. e.*, if both meters register the same with both connections, (a very improbable condition), no ready means of determining the correct connection exists and an induction motor should be started up or some other means taken to vary the power-factor.

* Precautions should be observed not to open the secondary of a current transformer while it is carrying load, as excessive potentials may thereby be generated.

These tests will give correct results whether the power-factor be lagging or leading in all the cases discussed except Case VI which cannot be differentiated from Case I by this means. However, this case would practically always be discovered by inspection.

The effect of incorrectly connecting a three-phase meter in measuring an induction motor load is indicated in Fig. 6, in which the kilowatt readings of a three-phase meter measuring the power input to a squirrel cage induction motor are indicated at various percentages of full load, both with correct connections and with the

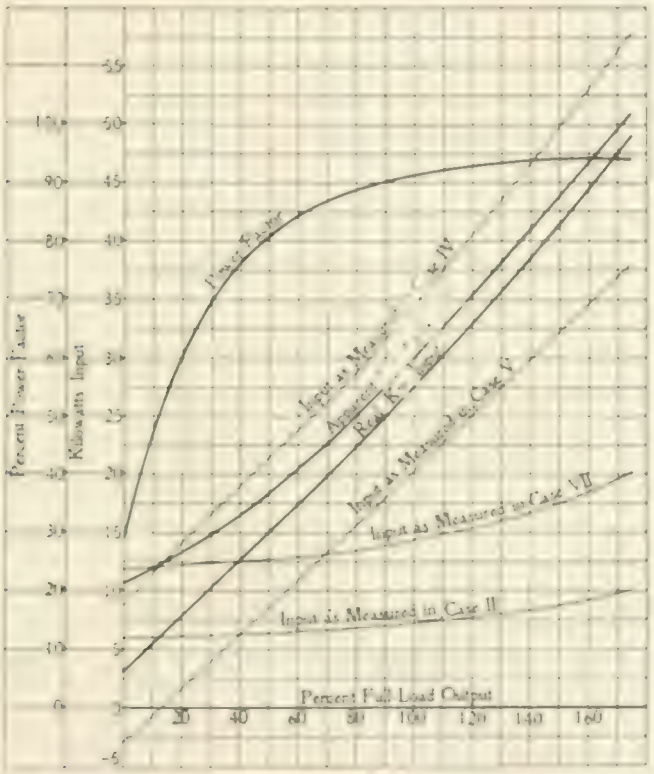


FIG. 6.—POWER REGISTERED BY METERS WITH VARIOUS CONNECTIONS AT DIFFERENT PERCENTAGES OF FULL LOAD OF A 30 HORSE POWER SQUIRREL-CAGE THREE-PHASE INDUCTION MOTOR

connections given in several of the above cases. The power-factor and apparent kilowatts input have also been plotted for comparison. It will be noted that the connections given in Case IV are the only ones in which an excessive reading is obtained. It is an odd coincidence that the relations of the power-factor curve, efficiency curve and the curve of total readings in Case II are such that when one of the meter elements of either meter is connected backward the polyphase meter will record approximately the same load, without regard to the load on the motor, the load reg-

istered being much less than the true load throughout practically the entire scale.

A question that frequently arises is:—Having discovered that a polyphase watthour meter or two single-phase watthour meters have been incorrectly connected, is it possible, knowing the nature of the incorrect connection, to determine what the true consumption of current has been? An exact solution is possible only in a rather improbable case, namely, that the average power-factor during the period covered by the incorrect connection can be accurately determined and that the phases are exactly balanced. Nevertheless, under ordinary industrial conditions, where three-phase motors only constitute the load, an average power-factor for the period may be approximately determined and it may be assumed that the phases are balanced. By inspection of Fig. 2 the ratio between the correct reading and the incorrect reading may be determined at the average power-factor, which will form the basis for a very fair estimate of the correct load. The accuracy of this estimate will depend entirely upon the accuracy with which the average power-factor over the given period may be determined. The method of making such an estimate may possibly be made more clear by an example. Assume that a three-phase watthour meter registers 810 kw-hrs., and that it has been discovered that it is incorrectly connected, according to Case II. Assume also that watthour meter tests, extending over a period of several days subsequent to the discovery and correction of the improper connection show an average power-factor of 80 percent. From Fig. 2 it may be seen that for Case II the correct reading at 80 percent power-factor is 1.39 ÷ 0.6 times the actual, and hence equals 1875 kilowatt-hours.

A STUDY OF LOAD-FACTORS

S. A. FLETCHER

THE IDEAL condition of operation for a commercial electric generating station is that of supplying a uniform load during the whole twenty-four hours of every day equal to the full capacity of the plant. This ideal is unattainable under practical conditions and even a close approach to it is possible only under very special conditions. For instance, a number of the hydroelectric power stations at Niagara Falls furnish energy principally to electric furnaces, electrolytic works, etc., and hence have a very

TABLE I—CHARACTERISTICS OF A TYPICAL LIGHTING STATION

Rated capacity of station, kilowatts	800
Overload capacity of stations (50 percent for one hour) kilowatts.	1 200
Turbo-generators—two units { Capacity of first unit — kilowatts	300
{ Capacity of second unit — kilowatts	500
Maximum peak, Summer — kilowatts	600
Maximum peak, Winter — kilowatts	800
Boilers, capacity (one spare) horse-power	350
Coal, bituminous run-of-mine, 13 500 B. t. u. (hand firing, natural draft) dollars per ton	2.25
Condenser, surface type, inches vacuum	27.5
Condensed steam returned to boilers.	
Steam consumption (dry saturated) full load, lbs. per kw-hr.	20
Steam consumption (dry saturated) average load, lbs. per kw-hr.	22
Evaporation, lbs. of water per lb. of coal	7
Coal consumption, average lbs. per kw-hr	3.13
No extra allowance for banking fires.	
No charge for cost of make up water.	
Cost of station complete, $125 per kw, dollars	10 000
Labor and supplies per year. Two twelve hour shifts with extra fireman's helpers * for peak load ($600 per year)	7 300
Fixed charges per year, 15 percent.	
(Interest 5 percent; taxes 1.5 percent; running repairs 1.5 percent; depreciation 4.5 percent; executive 2.5 percent: Depreciation is here considered as an amortization fund based on 15 year life, 6.66 per cent depreciation at 5 percent interest compound semi-annually.)	

uniform load. The ordinary central station, however, has considerable variation in power requirements during the day.

The load conditions of a generating station may be represented graphically by a curve, each point of which represents the actual load at a given time. A load curve of a central station which supplies power mainly for commercial lighting is characterized by a

* For conditions as shown in curves Figs. 5 and 6 an additional fireman's helper is required in the boiler room.

high peak during the early evening, tapering down to a very low value after midnight and continuing at a comparatively low value until the next evening peak. Such a plant is said to have a low load factor; that is, the ratio of the average to the maximum load, as shown on the curve, is low. The revenue of such a station can be largely increased, with the existing equipment, if a market can be found for power during the period of small demand, that is by filling in the valley of the curve.

The average daily load conditions on a certain 800 kilowatt steam turbine station in the first week of December are shown in Fig. 1. The characteristics of this station are indicated in Table I. The average output for 24 hours was 335 kilowatts, and the maximum output 700 kilowatts, making the load factor 47.9 per-cent. The lowest part of the load curve occurs usually from 11 P. M. to 7 A. M. and motor load during this time is thus especially desirable.

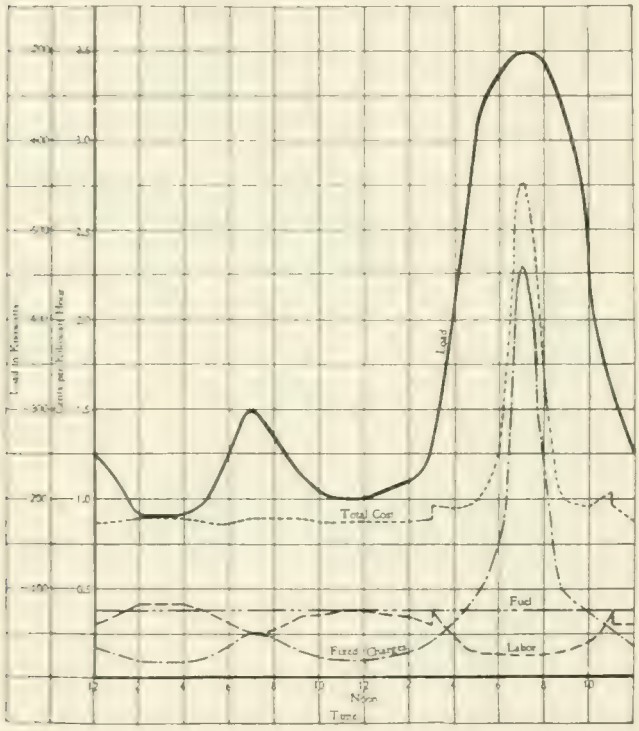


FIG. 1—LOAD CURVE AND CURVES SHOWING TOTAL AND DETAILED COSTS PER KILOWATT-HOUR, DISTRIBUTED CONTINUOUSLY

Night load can be obtained by installing motors in municipal and private pumping plants, newspaper printing offices, electro-chemical works, cold storage rooms, and by charging storage batteries, etc. From 7 A. M. to 5 P. M. almost every industry where power is required offers possibilities for motor installations that will raise the load curve, increase the load factor and reduce the average cost of producing a kw-hr.

In order to interest power users it is usually necessary to show the advantages of electric drive. While there are many advantages which might be enumerated, this discussion is limited to that of cost. Low power rates are not only attractive to prospective customers, but in many cases can be quoted with profit by the power com-

pany. There are a number of ways of distributing the costs of power generation and distribution and each of the more common methods may be said to have its advantages. The method outlined in the following discussion while not the most common, is one that is receiving considerable attention at the present time, and can, of course, be used in the laying out of schedules of rates made up on any other principle. The calculations are based on power cost at the switchboard; rates to customers must be based on these costs plus the cost of distribution. In fixing rates to lighting customers, the investment in transformers and meters and the cost of reading the latter must also be considered. This consideration tends to make the rate for energy delivered on the customers' premises for small lighting installations higher than the rate for motors or large lighting installations although the cost at the switchboard may be the same in both cases.

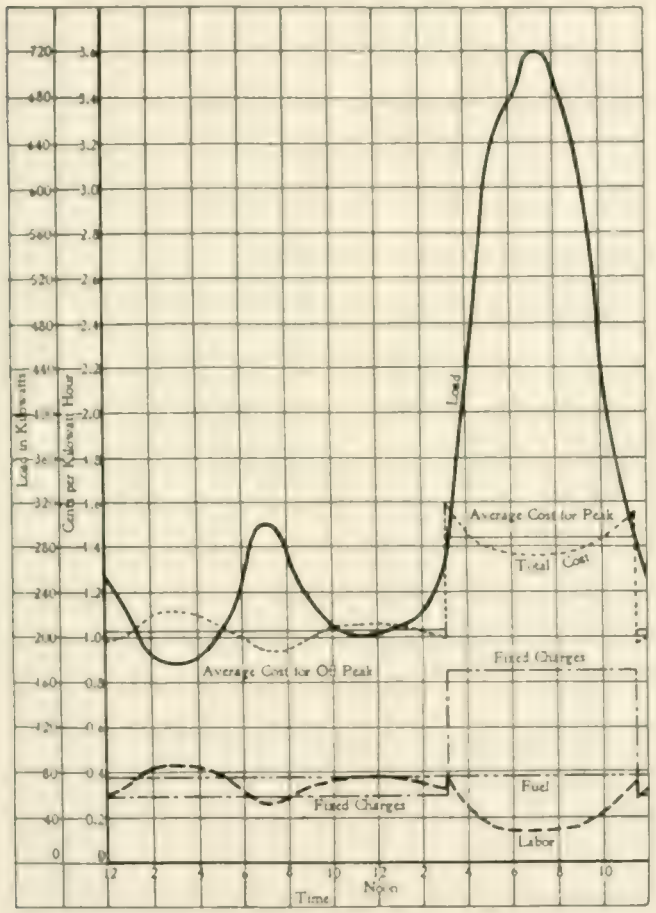


FIG. 2—LOAD CURVE AND CURVES OF COSTS PER KW-HR.

Fixed charges distributed according to units in operation.

The cost of manufacturing power is made up of two parts: the fixed charges which depend on the investment, and the operating charges which vary with the amount of power manufactured. The fixed charges include interest, depreciation, taxes and insurance. The operating charges include labor, fuel, water, oil and waste, etc., which, although they vary somewhat with the electrical energy generated, are by no means proportional to it. The ratio of the fixed to the operating charges depends upon the size and nature of the

installation and also on the plant load factor. As a general rule, unless the load factor is over 30 percent, the fixed charges will equal or exceed the operating charges. For very low load factors, such as exist in plants having a lighting load only, the fixed charges form the greater part of the total cost per kilowatt-hour.

In the plant under consideration, the period during which the load exceeds the average load lasts about eight hours; or from 3 P. M. to 11 P. M. (during the Summer the duration of this peak is still shorter). The station capacity must be large enough to carry the peak, and some generators must either be idle or running at reduced load during the remainder of the twenty-four hours. As each kilowatt of capacity requires a certain investment necessitating a fixed charge, it follows that the revenue per unit of capacity should be the same whether a generating unit supplies power for one hour or twenty-four hours. On this basis the fixed charge per kilowatt hour of the equipment which works continuously is very much less than for that which works only on the peak. Therefore, the fixed charge is divided so as to make each kilowatt of capacity bear its share of the fixed charge, the amount per kilowatt-hour being determined by the number of kilowatt-hours generated by each kilowatt of capacity.

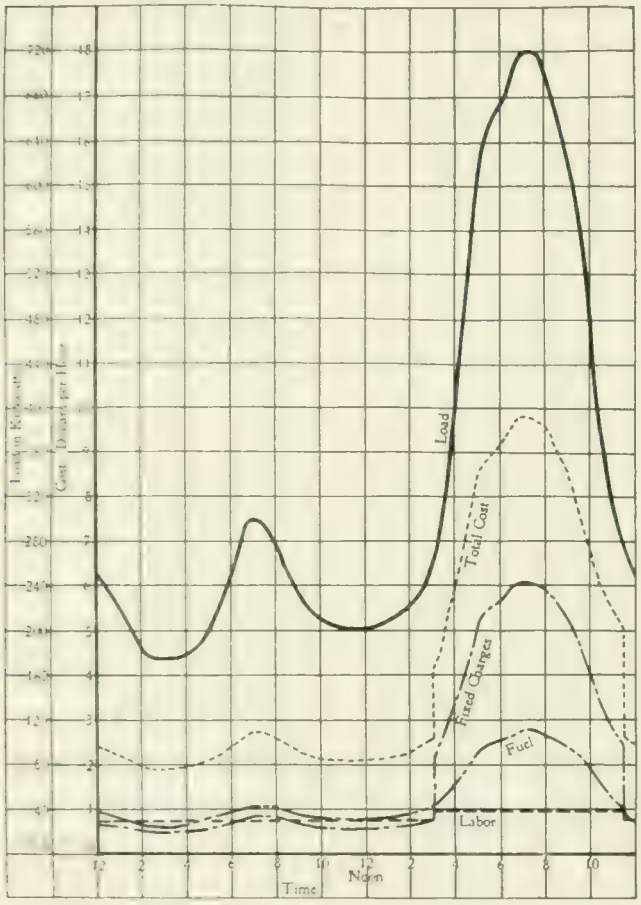


FIG. 3—LOAD CURVE AND CURVES OF COSTS PER HOUR

The kilowatt-hour costs of fuel, labor and fixed charges are shown in Fig. 1, as well as the total cost. The fuel cost per kilo-

watt-hour (which may be assumed to include water, oil, waste, etc.) is assumed to be constant regardless of load, a condition very nearly true when two or more units are installed and each unit may be operated at approximately a uniform load. The labor cost per kilowatt-hour decreases with increasing load and is therefore at its lowest value during the peak. The fixed charges are divided as explained in the foregoing paragraph, the larger part being distributed over the time of the peak.

While Fig. 1 shows what may be called the instantaneous costs per kilowatt-hour, the determination of such curves is difficult, so that for use in figuring costs it is preferable to adopt a slightly different method of distributing the fixed charges. The peak load makes necessary the greater portion of the investment and the fixed charges per day on that portion of the plant used only for the peak should therefore be distributed over the time during which the peak continues. The 300 kilowatt unit operates 24 hours and the 500 kilowatt unit operates but 8 hours. The 300 kilowatt unit causes three-eighths of the total fixed charge and the 500 unit five-eighths. Thus from the output of each unit the average fixed cost per kilowatt-hour may be figured. This makes the interest charge per kilowatt-hour constant during both the period of light and of heavy load, as indicated in Fig. 2, and therefore provides a system of determining the costs which is more readily used than the method shown in Fig. 1. All of the following curves will be based upon the method used in Fig. 2.

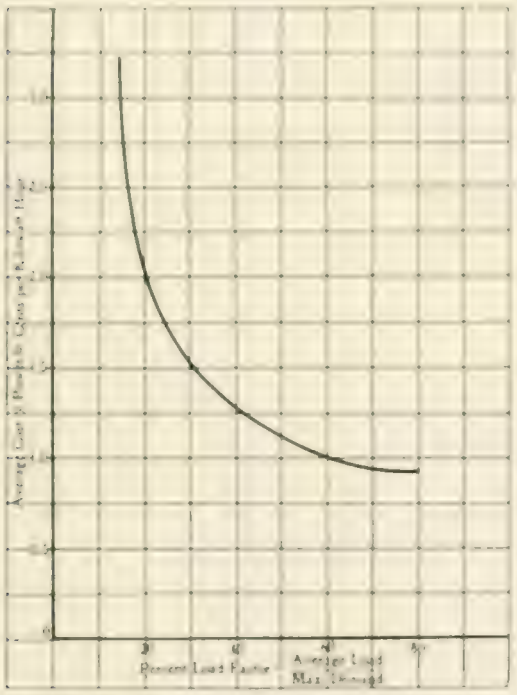


FIG. 4—CURVE SHOWING VARIATION IN COST WITH DIFFERENT LOAD FACTORS

The total charges vary as affected by the fuel, labor, and fixed charges, the average total charge being 1.43 cents per kilowatt-hour during the peak and 1.025 cents the remainder of the day. During the hours of low load, idle generating capacity is available; with fixed charges distributed as shown in Figs. 1 or 2, the cost of off-peak load depends almost wholly on operating charges and is

therefore low. In Fig. 3 the load curve is repeated and the hourly cost of all energy as well as that of the component parts, labor, fuel and fixed charge, is shown. These hourly costs are obtained by multiplying the cost per kilowatt-hour by the average load at various times.

The decreased average daily cost of energy per kilowatt-hour with increased load factor is shown graphically in Fig. 4. The general shape of such a curve is the same for all plants, although

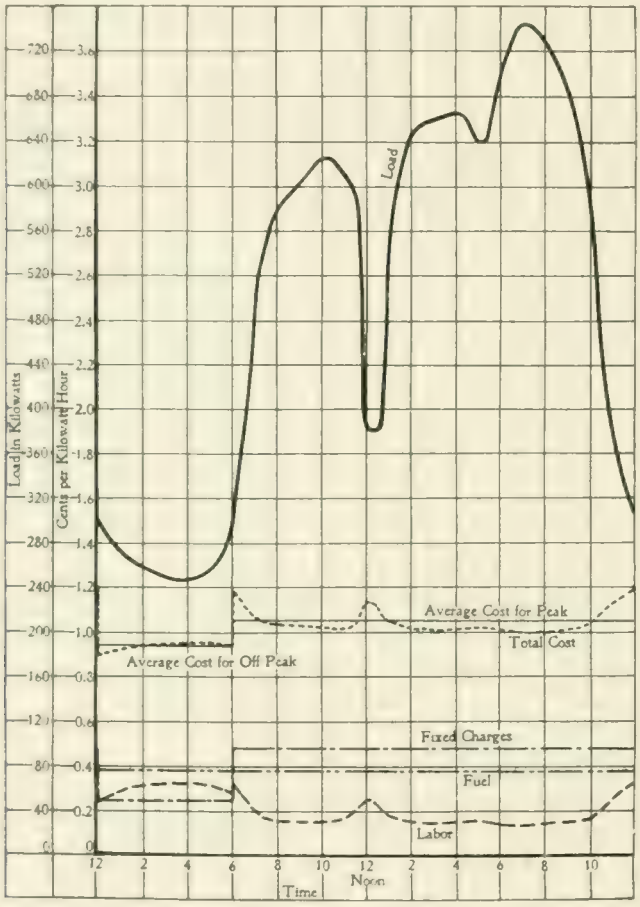


FIG. 5.—LOAD CURVE AND CURVES OF COSTS PER KW-HR. WITH LARGE DAY LOAD
Compare with Fig. 6.

the scale values may differ. This curve makes clear the fact that increasing the load factor by securing off-peak load decreases the cost of all energy generated during the 24 hours. This fact is made still more clear by Figs. 5 and 6, obtained by increasing the load factor on the station previously considered. The load curve shows practically the same maximum peak as before, but shows also the addition of a day load. The former station capacity is still ample, but the load factor has been raised to 63 percent, a value easily possible for many stations.

Special attention is called to the fact that not only the average total cost per kilowatt-hour has been lowered but also the average is less in both the period requiring the full generating equipment and in the period requiring only the smaller unit. These curves would show a somewhat decreased total cost if the actual hourly fuel consumption had been taken instead of assuming that the fuel cost per kilowatt-hour is constant regardless of the load.

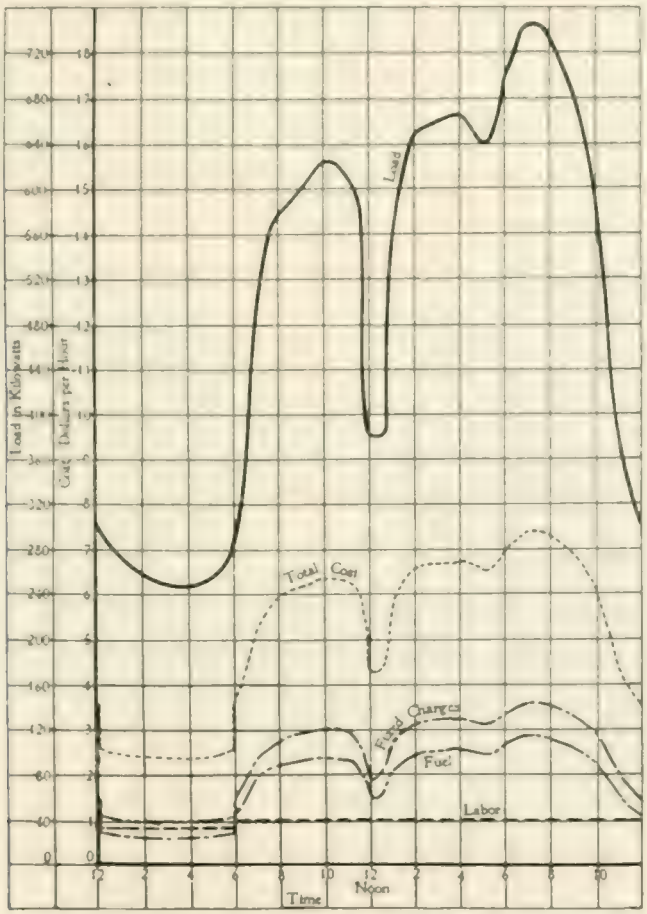


FIG. 6. LOAD CURVE AND CURVES OF COSTS PER HOUR WITH LARGE DAY LOAD
Compare with Fig. 5.

If it were possible to maintain nearly full load upon the station at all hours, that is, to operate with a load factor approaching one hundred percent, the total cost per kilowatt-hour would be maintained practically constant at the minimum value obtainable in this plant. When the lighting load is charged with the fixed and operating expense, a good off-peak load can be made to pay substantial dividends at a very moderate selling price.

AUTOMATIC MOTOR STARTERS AND CONTROLLERS FOR DIRECT-CURRENT MOTORS

DRIVEN LOADS HAVING SMALL INERTIA

H. L. BEACH

THE centrifugal pump and centrifugal blower or fan offer very good examples of that class of motor application where the driven load has small inertia and small starting friction. The usual way of coupling this class of apparatus to the motor is with the flange coupling as shown in Fig. 1. The load is sometimes driven by a belt but this is not the general practice unless one has a slow speed motor which is idle and it is desired to use it rather than purchase a new one. When motor and pump are direct connected the starting friction is very small, being only such as is occasioned by the weight of the moving parts. In this class of apparatus the normal running speeds are usually from 1 500 to 2 000 r. p. m. and the armature of the motor and the rotating parts of the pump are therefore comparatively small. Another characteristic of centrifugal apparatus is that the pressure generated by the pump depends entirely on the speed at which it is run, other things remaining constant. At constant speed, therefore, the pump will deliver a constant pressure and the volume of water delivered will depend upon the pressure against which the machine is working. If this latter equals the pressure which the pump generates no water will be delivered and no work will be done, so that the motor will have nothing to overcome except the general friction of the apparatus. This can easily be demonstrated by closing a valve across the opening leading from the pump, when it will be found that the load on the motor will decrease to a very small percentage of full load. If on the other hand, the pressure against which the pump is working be decreased, the amount of water pumped will be increased and the work done will increase so that the load on the motor will become greater and may easily reach a dangerously large amount.

A striking illustration of this fact recently came to the writer's notice. A tank was being kept full by a centrifugal pump and the water for the tank was being drawn normally from a well. Arrangements were made, however, whereby the city water supply could be connected and the water drawn from it. The city supply had a pressure corresponding to about 50 feet head of water and it was noticed that the actual load on the motor was considerably greater when drawing water from the city supply with its pressure tending to assist the pump than when taking water from the well

and doing all the work itself. It was noticed, however, that the time taken to fill the tank was much shorter in the former than in the latter case; this at first looked unreasonable but will be readily understood if it be assumed that the pressure worked against is equal to a 150 foot head and that the pump generated a pressure equal to a 200 foot head. Since the pump ran at approximately the same speed in each case its pressure was constant. When pumping alone there was a net pressure corresponding to a 50 foot head for pushing the water through the pipe, while when working from the city mains there was (200 + 50) − 150 = 100 foot head net pressure, which of course sent more water through the pipes and gave the motor a proportionately greater amount of work to do.

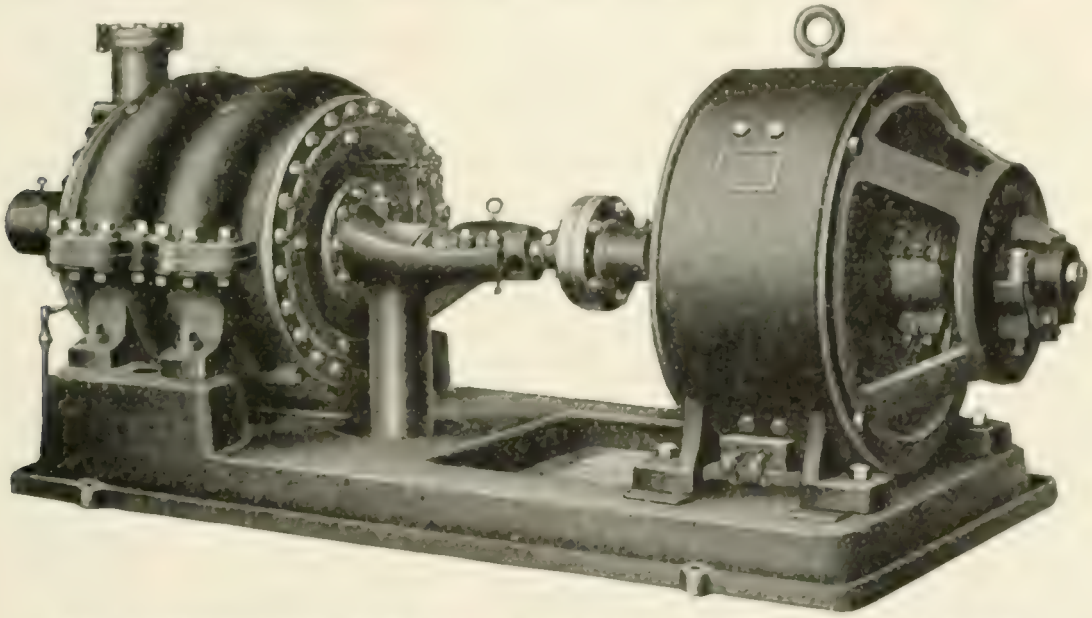


FIG. 1—CENTRIFUGAL PUMP DIRECT CONNECTED TO DIRECT-CURRENT MOTOR BY FLANGE COUPLING

This class of machine has, therefore, two peculiar characteristics. If the source of supply or the delivery pipe becomes closed the pump will do no work and the motor load will decrease to a very small amount. If the opposing pressure be removed the amount delivered and, therefore, the load on the motor will increase until the friction of the water through the discharge opening in the pump consumes the entire pressure generated by the pump. With high pressure pumps, of course, this will be several times full load on the motor. Blowers present exactly the same characteristics and it will be found that if the casing around a blower be entirely removed the load on the motor driving it will increase to such an amount as to either burn up the motor or blow the fuses.

Considering therefore a pump or blower, what kind of a motor

is best fitted for this class of service? Obviously a series motor whose speed increases as the load decreases would not be a very safe motor to use if there were any chance whatever of the supply or delivery openings being closed, for then the motor would run away. On the other hand, if the discharge pipe were to become broken so as to relieve the back pressure, the motor might slow down sufficiently to reduce the pressure of the pump until a balance of speed and pressure would be reached just below the setting of the fuses or circuit breaker which, being set for the usual overload starting peaks, would allow the motor to draw current enough to damage it in a short time without opening these safety devices. The other extreme of the series motor is the shunt motor and for many applications it is the proper motor to use. In the case of stoppage of discharge or supply conditions the speed remains practically the same irrespective of the decrease in load. In case of a break in the discharge pipe the speed does not decrease as with a series motor and the load on the motor will, therefore, be much greater and will open the protective devices.

There are, however, some applications where the shunt motor is not ideal for this work. Where the motor is connected to a feeder circuit having large fluctuating load, as at the end of a long trolley line feeder, the compound wound motor will hold the load much more constant than the shunt, as the fluctuating voltage on the motor causes fluctuation of armature current which, in flowing through the series field winding, changes the field strength of the motor and tends to make it maintain constant speed. Again, consider a private power plant operating to run the machinery and light a big office building; the larger part of the load on the plant will be for lighting and, therefore, it will be very desirable to keep the voltage absolutely constant to prevent flickering of the lights. In addition to the lights the power plant may supply water power pressure for operating one or more hydraulic elevators, and the load on the elevators being variable, the pressure can be kept up very efficiently by a centrifugal pump operated by a motor. The pump must necessarily be built to care for the maximum demand on the elevator and since this is not constant it will be obvious that the pump will not be required all of the time; in fact, the demand on the pump will be extremely intermittent. The automatic starter now comes into use and is arranged to be operated by a pressure gauge so as to keep the water pressure for the elevator between

fairly close limits. This means that when the pressure gets to a certain maximum amount the pump will be stopped and will remain so until the pressure decreases to a certain definite value, at which time the pressure gauge will operate the starter and start the pump again. If the lights flicker every time this pump starts, complaints will undoubtedly arise. The actual load on the motor may not be sufficient to disturb the system but if the acceleration current rises to about double full load on each notch the disturbance may be quite noticeable. There are two ways by which this current peak may be reduced. With a shunt motor, a large number of steps can be put in the starting mechanism or a different type of motor can be used. The larger number of steps increases the complication and cost of the starter and it will be found that the additional cost will usually be considerably more than the additional cost of a different type of motor.*



FIG. 2—FULL AUTOMATIC DIRECT-CURRENT MOTOR CONTROL PANEL, OPERATED BY PRESSURE GAUGE MASTER SWITCH

This discussion illustrates a case where the operating conditions have modified what would otherwise be a good application for a shunt motor. Where a hand starter is used or where a motor is to run for long intervals of time such as for a day, the shunt motor is the proper motor for the work. Where frequent starting is required it is not the proper motor and unless very constant speed is required a compound wound motor will give far greater satisfaction in every respect. A recent design of full automatic self starter such as would be used with the elevator pump above described is shown in Fig 2. This class of service may be very severe on the control mechanism as the demand is likely to be very intermittent. The writer knows of one installation of this kind where the pump starts on an average of every minute and

* By reference to Fig 3 in the article by the writer in the Journal for August, 1912, p 724, it will be seen that the current peaks with a shunt motor reach 165 percent of full load and that with a compound motor the peaks reach only about 145 percent of full load, while with a series motor the current peak is only 130 percent of full load.

runs 30 seconds. As an illustration of the small amount of power required by a centrifugal pump when not generating pressure enough to overcome the load, this particular pump would sometimes run as long as 20 seconds after the power was shut off. A check valve in the discharge line prevented the water discharging back through the pump. A connection diagram for a starter for a motor driven pump is shown in Fig. 3.

In place of repeatedly starting and stopping the motor in a case of this kind, one way to decrease the work on the control

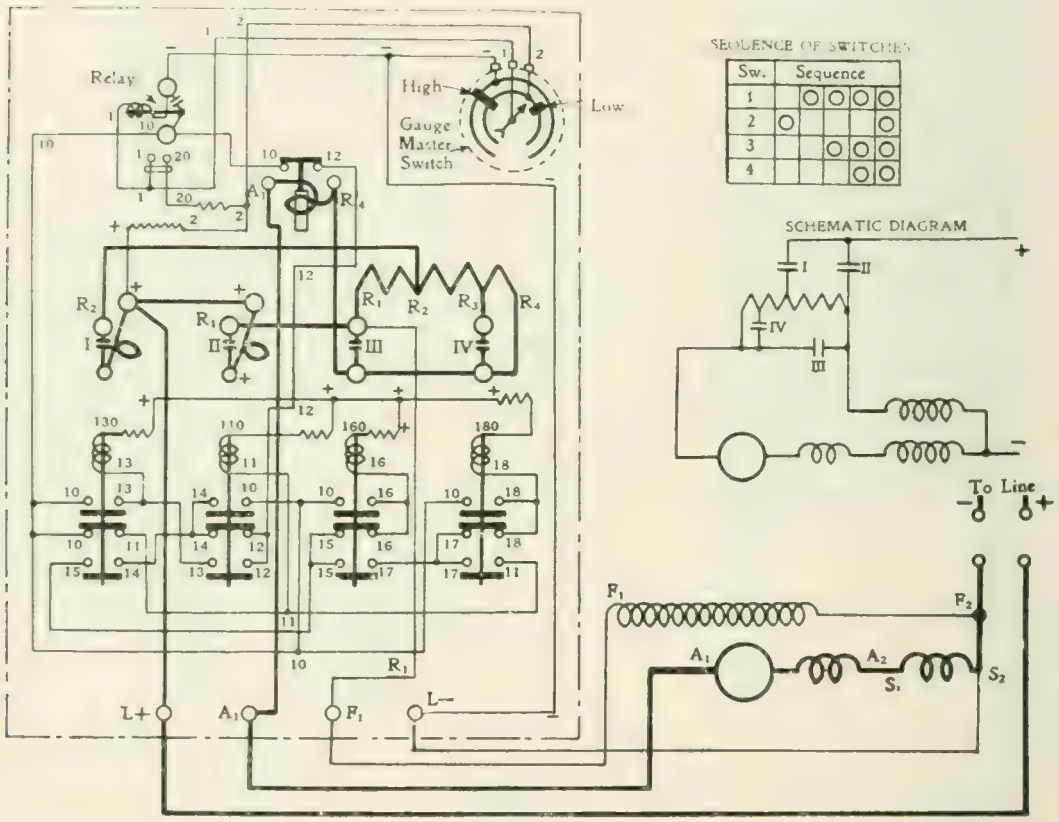


FIG. 3—SCHEMATIC DIAGRAM OF CONTROL PANEL

It wil be noted that Swith *II* is closed by the voltage relay, which is energized by contact at the low pressure pin, and released by contact at the high pressure pin. Switches *I*, *III*, *IV* and *II* are then closed in succession, each energized by the secondary contacts of the preceding switch, and delayed by the action of the current relay.

mechanism and at the same time give the same results is to take advantage of the speed-pressure characteristics of the centrifugal pump and provide an adjustable speed motor for driving it. The low speed of the motor is arranged so that the pump will not deliver water against the load, and the starter is arranged so that the pressure gauge cuts in resistance in series with the shunt field at low pressure, thus speeding up the motor, and cuts out the re-

sistance at high pressure thus slowing down the motor. This scheme not only cuts down the work on the control mechanism but since the motor is already up to nearly full speed when the pump begins to deliver water the line disturbances become very small on cutting in or out the field resistance.

A question that is very frequently asked in connection with starting this class of apparatus is: "Why not let the motor start with light current, and increase it as the load comes on; in other words, instead of each peak during the start having the same maximum, why not start it as shown in Fig. 4?" In the first place, when starting as shown in Fig. 4, a motor takes greater increments of starting current on each notch, thus giving greater fluctuations in starting torque and correspondingly greater strains on the pump mechanism. Second, the last peak will reach at least as high a value as when accelerating with peaks of uniform maximum values, and third, the motor will run on resistance for a longer period of time and will therefore start less efficiently, since the power loss in the resistance will be greater. This latter is of little importance when starting twice a day but should be considered when starting every minute or so, as in the case illustrated. The actual power used by the motor will be practically the same in the two cases for the same amount of work will have to be done. A high rate of acceleration is therefore very desirable and acceleration such as that illustrated in Fig. 4 is not ordinarily desirable.

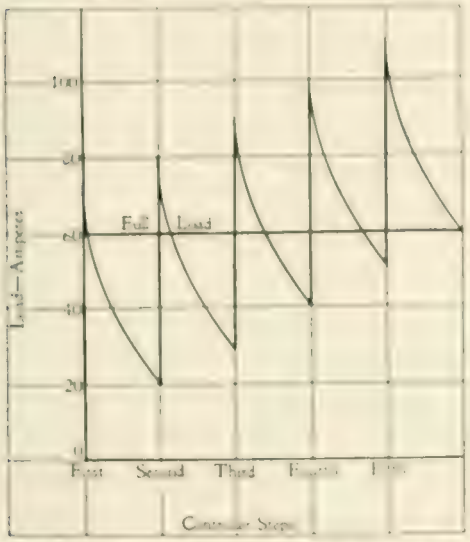


FIG. 4 MOTOR CURRENT CURVE SHOWING SUCCESSIVELY INCREASING STARTING CURRENT STEPS

SINGLE-PHASE COMMUTATOR MOTORS

TYPES INVOLVING USEFUL INTERNAL TRANSFORMER ACTIONS (Continued)

R. E. HELLMUND and E. W. P. SMITH

REPULSION MOTOR

THE previous article explains how the transformer effect possible in alternating-current motors can be used to induce the required current to flow in the compensating winding. The same principle can be used in a reverse manner by sending the line current through the compensating winding and by short-circuiting the armature, in which case the transformer action between the compensating winding and the armature is depended upon to set up the desired currents in the armature. This can be easily seen by reference to Figs. 3*a* and *b*. Fig. 3*a* shows again the plain series motor and indicates the current directions in the series circuit. A motor is shown in Fig. 3b in which the line current flows through the main field and compensating winding only. As previously pointed out, in such a case a cross flux is obtained which interlinks with the compensating winding and the armature, and this flux will set up a current in the armature which is opposite in direction to the current in the compensating winding, if the magnetizing current necessary to set up the cross flux again be disregarded. Then the current directions in the armature will be as indicated in Fig. 3b, and by comparing this figure with Fig. 3a, it will be observed that the current relations in the field as well as in the armature are exactly alike with these two connections; therefore, there is no reason why the two motors should not operate the same. The only difference between the two motors is that the armature current is conducted into the armature in Fig. 3a while it is induced by transformation in Fig. 3b. The motor of Fig. 3b which is commonly called the "repulsion motor" is, therefore, no-

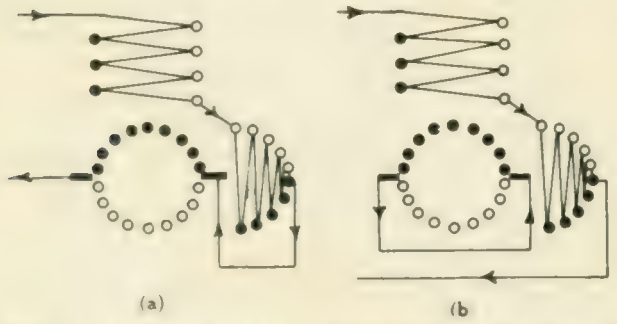


FIG. 3 (a) AND (b)—CONNECTION DIAGRAMS SHOWING RELATIONS BETWEEN PLAIN SERIES MOTOR AND REPULSION MOTOR

thing else than a series motor in which the current and the energy is transferred into the armature by transformer action instead of by conduction. This motor might well be termed an "indirectly fed series motor." In this motor the compensating winding is no longer a winding for the purpose of compensating the armature cross field, but it serves principally as the primary winding of the transformer. It will therefore be referred to in the following as the cross field stator winding or briefly as the cross field winding. It may also be termed a "transformer field," for it serves principally as such. The main field may also be called the "torque field," as it is the field which produces the torque. The working

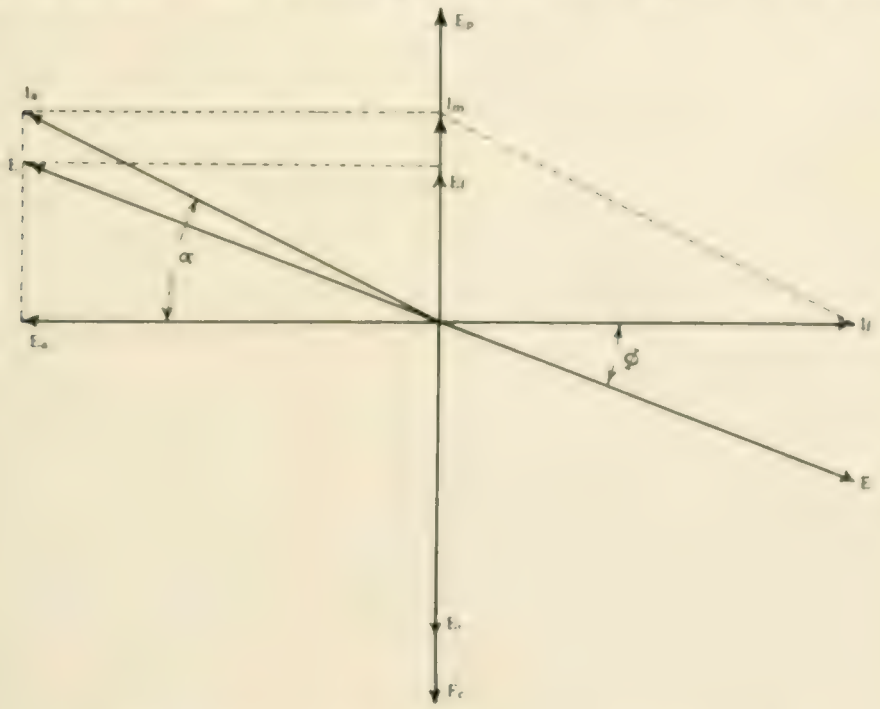


FIG. 4—SIMPLIFIED VECTOR OF REPULSION MOTOR

principle and the transformer effect in the repulsion motor may be explained somewhat more in detail by the diagram of Fig. 4. In order to simplify the introductory step of the discussion as much as possible, the effect of the ohmic drops and leakage reactances has been neglected in this figure.

The diagram of Fig. 4 is based on the following considerations: The cross field necessary to transfer energy from the cross field winding to the armature is set up by a magnetizing current *Im*, which is the resultant of the current *If* and *Ia*. *If* is the current in the cross field winding, and *Ia* is the current in the armature. The size and direction of the cross field *Fc*, and the result-

ant magnetizing current Im, which magnetizes the cross field, is determined by the condition that the cross field must induce a voltage in the armature which is equal and opposite to the counter-electromotive forces set up in the armature. Since in the present discussion the ohmic drop and the leakage reactance voltage are neglected, the only consideration is the counter-e.m.f. in the armature which is set up by rotation. This counter-e.m.f. is in phase with the main field of the motor, which, in turn, is in phase with the current If flowing in the cross field and also in the main field winding. It follows therefore that the resultant magnetizing current Im must be at right angles to the current If. It is evident that the cross field not only induces an e.m.f. Ea in the armature, but that it induces under the assumption of an equal number of turns, the same e.m.f. in the compensating or cross field winding. If to this counter-e.m.f. Ea of the cross field be added the inductive voltage, Ef, which is induced in the main field winding and lags 90 degrees behind the field current If, the total counter-e.m.f. $= -E$ of the motor is obtained, and the voltage E opposite in phase and equal to this voltage, represents the voltage which must be impressed upon the motor.

The angle Φ between E and If, determines the power-factor of the motor. One of the principal differences of this motor in its operation as compared with the series motor, lies in the fact that the armature current is out of phase with the main field, and the counter-e.m.f. As long as the field and the armature current are in phase with each other, the alternating-current motor has a torque proportional to the product of the effective value of the field multiplied by the effective value of the armature current, just as in a direct-current motor. As soon as the two values are out of phase, however, the torque of the motor is proportional to the product of effective field value, times effective armature current, times the cosine of the angle α of phase displacement between the two components. Since the cosine of this angle is always less than unity, the phase displacement means a reduction of torque, under the assumption of equal field and equal current. This, in turn, means that the output of a repulsion motor is somewhat smaller than the output of a series motor of the same size.

While it was pointed out that the phase displacement between the cross winding current and the armature current is very small in a motor with short-circuited compensating winding, on account

of the fact that the cross field is very small, attention should here be called to the fact that in the present case, which in a way is the reverse of the one above mentioned, the cross field is comparatively strong because it must not only induce voltages to overcome the ohmic resistance and the leakage reactances in the armature, but also the rotational counter-e.m.f. therein, which forms an appreciable percentage of the total motor voltage. Since the cross field must be comparatively strong, it requires a comparatively large magnetizing current, Im, to set up this field. This in turn means that the angle γ is not by any means negligible as was found to be the case in the series motor with short-circuited compensating winding. The strong cross field, has, however, one advantage, in that it has a favorable influence upon the commutation.

The effect of the cross field upon the coils under commutation is very similar to the effect of the cross field of a shunt connected commutating pole in the case of the series motor. The voltage induced by the cross field, due to the rotation of the armature in this field, is of course in phase with the field, and, as will be seen from the diagram, it is in direct opposition to the voltage Ef, which is induced by the fluctuations of the main field, and which lags 90 degrees behind the field current If. It can be shown that under certain assumptions and with sinusoidal distribution of the main field as well as the cross field, and other assumptions made for the derivation of the diagram, that the two voltages Ef and Ei are exactly equal and opposite when the motor is running at synchronous speed. Even if not all of the above assumptions are fulfilled, the same results are obtained somewhere near synchronous speed. This means that when a repulsion motor is running near synchronous speed, the short-circuited voltage is practically compensated for, and that the sparking voltage is, roughly, the same as the reactance voltage of the armature. Since the latter is often very small, a repulsion motor will operate satisfactorily with regard to commutation near synchronous speeds, without special commutating pole windings or the like.

Instead of winding the stator of a repulsion motor, with a concentrated main field winding, and distributed cross field winding, it is possible also to distribute the field winding over a number of slots in the stator. This is diagramatically indicated in Fig. 5, in which the main field winding occupies four slots of the stator, while the cross field winding occupies 20 slots of the stator, as

indicated. An inspection of this figure shows that the current in all of the stator slots below the line XY, which is shifted an angle β against the center line of the brushes, is of one direction, while the current on the other side of the line XY is in the opposite direction. This means that it is possible to use, instead of two separate windings for the main field and cross field windings, one single winding as shown in Fig. 6, the center line of which is inclined by the angle β from the center line of the brushes. A comparison of Figs. 6 and 5 with regard to the signs indicating the current directions in the two figures, shows that

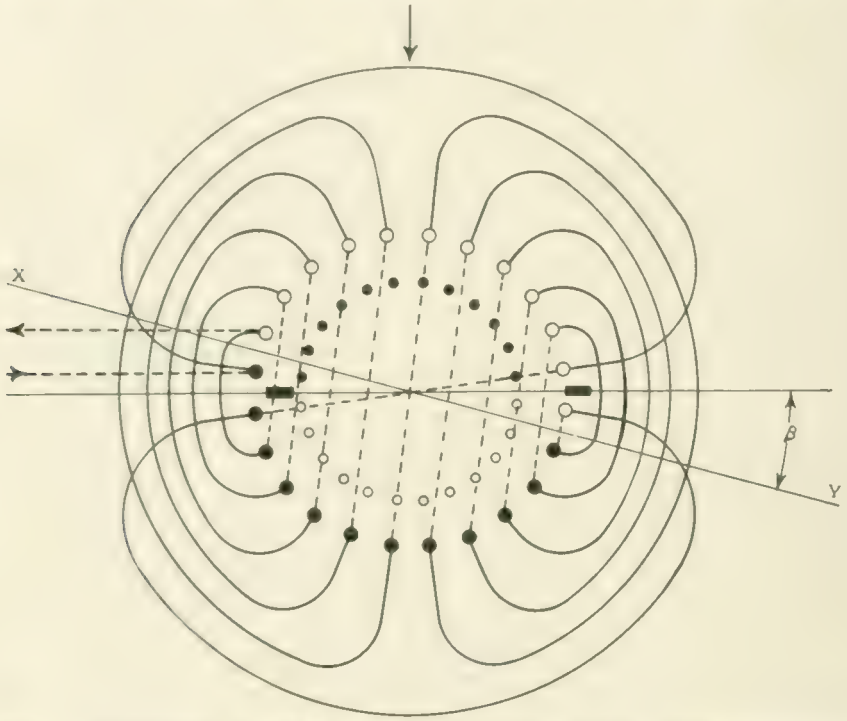
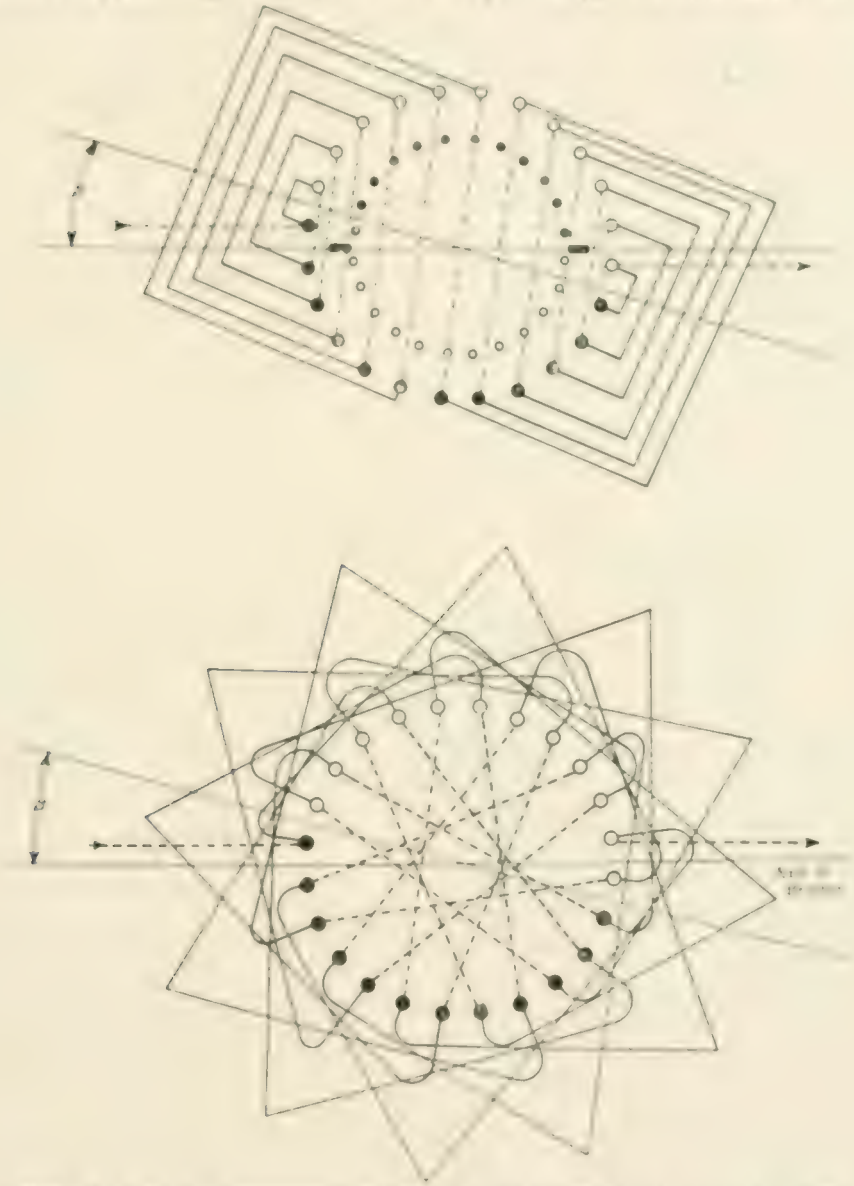


FIG. 5—WINDING DIAGRAM OF REPULSION MOTOR WITH SEPARATE MAIN FIELD AND CROSS FIELD WINDINGS
Both windings are of the distributed type

these latter are exactly alike, and it is therefore evident that the motor of Fig. 6 will operate in exactly the same manner as the motor of Fig. 5. All that is necessary in considering the performance of the motor in Fig. 6, is to consider all wires on both sides of the center line of the brushes and as far as included by an angle β at each side of the center line, as the main field turns; all other wires are to be considered as cross field turns. Instead of making a concentric winding as shown in Fig. 6, it is also possible to use a progressive winding with form-wound coils of uniform design as shown in Fig. 7. The arrangements of Figs. 6 and 7 are the ones usually

used in preference to the ones shown in Fig. 5, since a single winding of course is in practice much simpler than two separate windings. The diagramatic sketches of Figs. 8 and 9 show the customary way of representing the repulsion motor connection diagram, corresponding to Figs. 6 and 7. Fig. 10 indicates the usual



FIGS. 6 AND 7.—WINDING DIAGRAMS OF REPULSION MOTOR WITH MAIN FIELD AND CROSS FIELD WINDINGS COMBINED IN ONE.

Fig. 6 shows a concentric coil winding, while Fig. 7 illustrates use of diamond type coils.

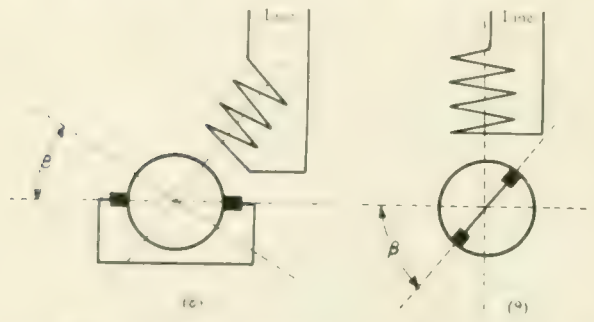
way of representing the motor shown in Fig. 5, except that usually the connection *AB* is omitted, since it does not carry any current and is therefore not needed.

As has been shown in the above, in the repulsion motor, the phase displacement between the armature current and the main

field is unfavorable as it reduces the rating. This can be avoided by connecting the motor as shown in Fig. 11. Here the main field winding is connected in series with the armature while the cross field winding is supplied with the line current. In this case the field and the armature current will again be in phase as with the series motor. On the other hand, it is necessary to set up a cross field sufficiently strong to induce in the armature not only a voltage equal and opposite to the counter-e.m.f. of the armature, but in addition to that a voltage to overcome the inductive voltage of the field. Moreover it is no longer possible to combine in this motor the cross field winding and the main field winding into one. Also, other advantages of the straight repulsion motor must be sacrificed in order to gain the advantage of having the field and the armature current in phase. Therefore the arrangement of Fig. 11 is not used very much in practice.

DOUBLE-FED SERIES MOTOR FOR OVER SYNCHRONOUS SPEEDS

It was mentioned that in a repulsion motor the pulsating short-circuited voltage is properly compensated for near synchronous speeds. At higher speeds, the voltage induced by rotation on account of the cross field will increase, while the short-circuited voltage remains unchanged, under the assumption that the load remains unchanged; if the load changes, the short-circuit voltage changes. There is, therefore, a resultant sparking voltage which will continuously increase with the speed of the motor above synchronism, and consequently repulsion motors usually spark very seriously for speeds of 125 percent of synchronous speed and above. It is evident, however, that this could be avoided if it were possible to weaken the cross field. This can be done by setting up a cross field which does not induce the entire voltage necessary to overcome the counter-e.m.f. in the armature, but only strong enough to induce a part of this voltage. The remaining part of the voltage necessary in the armature can then be taken directly from the line or rather from a transformer connected across the line. The connection of Fig. 12 shows such an arrangement which is usually termed a "double-fed series motor," because it is partly

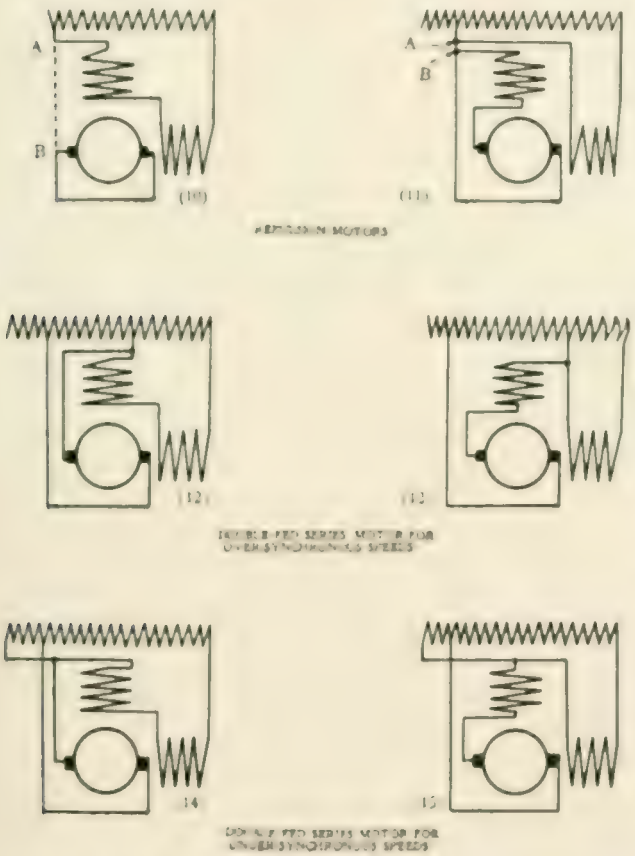


FIGS. 8 AND 9—CONVENTIONAL METHODS OF INDICATING REPULSION MOTOR CONNECTIONS

fed directly by induction and partly fed indirectly by transformer action. This connection, like the one in Fig. 10, has the disadvantage that the field and armature current are not necessarily in phase with each other. This condition, however, can be fulfilled by using connections as shown in Fig. 13. This method is commonly used in practice, and gives very good results for motors which are operated above synchronous speed.

DOUBLE-FED SERIES MOTOR FOR UNDER-SYNCHRONOUS SPEEDS

For motors which are to be operated below synchronous speed, the straight repulsion motor will have a cross field which is too weak to fully compensate for the pulsating voltage in the armature. Therefore, it is desirable to strengthen the cross field, and this can be done by setting up a cross field sufficiently strong to induce in the armature a voltage which is larger than the counter-e.m.f. in the armature. In this case, there will of course be a resultant voltage in the armature which can be taken care of by connecting the armature in the opposite direction to the transformer, as shown in Fig. 14. In this case, the stator winding takes energy from the line which is in excess of the energy for driving the motor and the excess energy is fed back into the transformer by the armature. Fig. 15 has the same relation to Fig. 14 as Fig. 13 has to Fig. 12, which means that it is a modification of Fig. 14, the purpose of which is to get the armature current and the field into phase with each other. Neither of the arrangements shown in Figs. 14 and 15



FIGS. 10, 11, 12, 13, 14, AND 15.—FUNDAMENTAL TYPES OF SINGLE-PHASE COMMUTATOR MOTORS

In which useful energy is transferred from the stationary member to the armature by transformer action

are used very much in practice, since motors with normal speeds below synchronous speed are not very common.

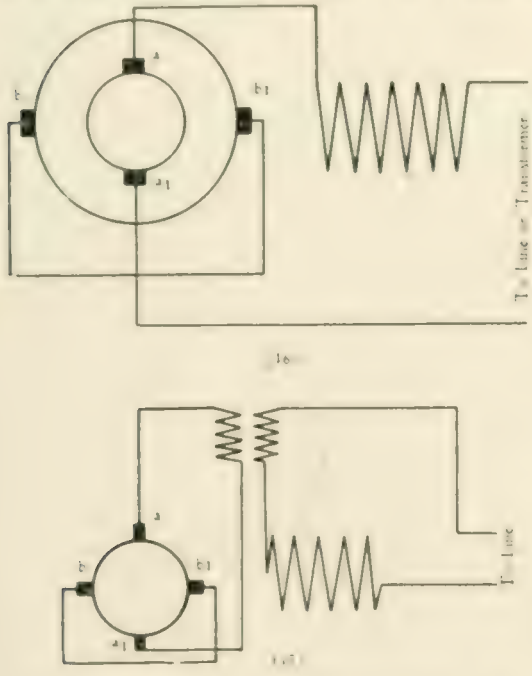
MOTORS WITH ARMATURE EXCITATION
(WINTER-EICHBERG MOTOR)

Nearly all types of motors with armature excitation make use of the internal transformer action in some way or other. It may be sufficient, however, to explain briefly only the Winter-Eichberg motor, as an example. This motor is a special type of indirectly fed series or so-called repulsion motor. As in the latter, the armature energy is transmitted into the armature by a cross field. The main field, however, is not induced by putting the main field winding on the stator, as in all motors previously described, but it is induced by currents sent into the armature. The principle of this scheme can best be explained if it first be imagined that the armature has two separate windings and two separate commutators as shown in Fig. 16. One of these windings serves the usual purpose of carrying the working current, while the other winding, the brush axis of which is shifted 90 degrees relative to the first winding, is supplied with current which serves the purpose of setting up the main field, in the same direction as it is usually set up by the field winding on the stator. Instead of having a separate armature winding, it is possible to use a single or common winding by introducing an extra pair of brushes as shown in Fig. 17, and, instead of sending a series current through the armature, to use a separate transformer. This connection is the one known under the name of the "Winter-Eichberg" motor. The advantage of this connection is that it will give a motor with unity power-factor. It is evident that the cross field, which extends over the working surface of the armature, not only induces a voltage in the coils short-circuited by the main brushes, but also induces voltages in all of the armature coils, which add up to give quite an appreciable voltage between the auxiliary brushes. Now as this voltage can be made equal and opposite in phase to the inductive voltage set up by the self-induction of the main field, it will be seen that instead of taking a voltage from the line necessary to overcome the self-inductance voltage of the main field, this motor induces such a voltage within itself. It can even be arranged so that the cross field induces a voltage somewhat in excess of the inductive field voltage and sufficiently large to take care of the leakage reactance voltages as well. This being the case, the motor does not have to take

any wattless voltage from the line, which means that it will operate with unity power-factor. The same principle is made use of in a great many other types of motors.

FUNDAMENTAL TYPES OF SINGLE-PHASE COMMUTATOR MOTORS

In conclusion, special attention should be called to the similarity of the arrangements of Figs. 10 to 15 inclusive. In all these windings, the current can be considered as flowing through the cross winding of the stator, the main field winding, and the armature in series, as shown for instance in Figs. 12 and 13. A special tap is provided for, however, in Fig. 12, between the armature and main field winding and, in Fig. 13, between the cross stator winding and the main field winding. Fig. 10 may be considered to be the same connection as Fig. 12; the special tap, however, is shifted to the left until it reaches the tap to which the armature is connected, thereby short-circuiting the armature, and leading to the so-called repulsion motor connection. If the tap is shifted still further, the case of Fig. 14 is obtained. In the same manner it will be observed that in principle the connection of Fig. 11 is obtained by shifting the tap of Fig. 13 to the left, until it coincides with the armature tap. By still further shifting the tap, the case of Fig. 15 is reached. The connections of Figs. 10 to 15 may therefore be considered as fundamental connections. The schemes of Figs. 6, 7, 8 and 9 respectively, are really the same scheme as Fig. 10, the only difference being that the two stator windings are combined into one. The same modification would be possible for the connections of Figs. 12 and 14. In all of these connections (Figs. 5, 6, 7, 8, 9, 10, 12, 14) the armature current is out of phase with the field, and all of them can be traced back to the connection of Fig. 12. In the diagrams of Figs. 11, 13, and 15, the current in the armature is always the same as in the field. All of these connections may be traced back to the connection of



FIGS. 16 AND 17.—CONNECTION DIAGRAMS SHOWING REPULSION TYPE MOTORS WITH ARMATURE EXCITATION

Fig. 13. A further step may therefore be taken in looking at this matter by considering Figs. 12 and 13 as the only fundamental connections, and all of the others as special cases of these two. Also, the Winter-Eichberg motor is simply a modification of Fig. 12, but it has the peculiarity of having the main field induced by armature currents and giving a power-factor of 100 percent under certain conditions. The series motors with short-circuited compensating winding may be considered as a special case of the connection shown in Fig. 13. It may be seen that a series motor middle tap in Fig. 13 is shifted to the right until it coincides with the tap of the compensating winding.

This discussion is obviously not intended to give a detailed description of the various connections, or the theory relating to each, but simply to give a brief outline of the various types, some of which may then be discussed more in detail. Neither is it intended to give a complete list of all types of motors which make use of internal transformer action in some way or other. A number of the more important examples are given in order to demonstrate the principles as applied for various purposes. The combinations and motor connections made possible by the utilization of the internal transformer action with or without armature excitation are almost inexhaustible.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

767—Two-Phase Motor Operated on Single-Phase Circuit—Can a two-phase, 60 cycle, 220 volt, four-pole, 1800 r.p.m. squirrel cage motor with 24 slots and 12 coils be operated satisfactorily on a single-phase circuit without rewinding the stator? T.F.B.

This is covered by an article on "Polyphase Motors on Single-Phase Circuits" by G. H. Garcelon, in the JOURNAL for August '05, p. 501, from which the following is quoted:—

"The characteristics of the motor will not be as good on single phase as when operated on a two-phase circuit for which it is designed, and some special device will have to be employed to make it self starting. Motors with squirrel cage rotors in general give better performance under abnormal conditions than wound secondary motors. With a given slip and given temperature rise, operation on single phase circuit will reduce the available capacity to approximately 70 percent of the normal polyphase rating. The maximum running or pull-out torque will be decreased one-half or one-third, depending upon the slip; the motor having the smallest slip gives the greater pull-out torque. The efficiency and power factor will be in general, highest at 70 per cent of the normal polyphase load but will be from 6 to 12 percent lower than with normal operation. As a single phase motor, the machine will not develop any starting torque; it is not necessary, however, to bring the motor up to more than one-fifth of normal speed in order to allow it to pick up, provided the load is very light. Hence, unless the motor is too large, it may usually be started by vigorous pull on the belt. If it is desired to make the motor self starting this can be accomplished by using resistance, inductance or capacity in one or more of the phases, in this manner the current in the different circuits is thrown out of phase (or split) which will give a rotating field of limited strength or sufficient to produce a small torque. There will of course be a large loss in the resistance or whatever device is used to split the phase; it is therefore generally cut out after the motor has picked up speed."

768—Alternator with Pair of Poles Short-Circuited—If a field coil on a revolving field alternator becomes so damaged as to require its removal would it be possible, by disconnecting the next pole also, and putting a jumper in the place of these two coils and their pole pieces, to continue to run the machine in parallel with other machines operating at the same frequency as the rated frequency of this machine without changing its speed? That is, all other conditions of the machine being normal, will removing one (adjacent) pair of poles of a revolving field alternator affect the frequency of the generated current, and if so, how and why? O.M.W.

The frequency of an alternating current generator is determined by the angular pitch between adjacent poles, so that the disconnection of a single field coil or of a pair of field coils will not affect the frequency providing the speed is not changed It will, however, reduce the terminal voltage in the ratio of one pole or one pair of poles to the total number of poles or pairs of poles. For example, if the alternator has 20 poles or 10 pairs of poles, the removal of one field coil will reduce the voltage 5 percent. A generator can be operated with some of the field coils disconnected as you propose provided the armature winding is all in series, but if there are parallel circuits in the winding the two circuits in parallel may have different voltages generated in them in such a way as to cause dangerous currents to flow from one parallel circuit to the other. If only one field coil is damaged, it is not necessary to cut out a second coil, provided the field windings are all in series. If they are in two parallels, then a second coil should be cut out in the other circuit, preferably diametrically opposite to the first coil, to avoid unbalanced magnetic pull. If a single coil is cut out, there will be some unbalanced magnetic pull on the rotor. With two adjacent coils cut out, this unbalanced pull will be practically doubled

Therefore, if one coil cut out shows too much unbalanced pull (as indicated by vibration of frame, in some cases), then an opposite coil can be cut out to overcome this. F.D.N.

769—**Overheating of Railway Motors on Low Voltage**—We have had some trouble with overheating of our railway motors as our service is rather severe for the size of equipment installed. We have been told that low voltage causes series motors to overheat. If this is true, please explain why. W.C.MCB.

A properly selected car equipment with good line voltage will perform its service with considerable period of coasting (5 to 10 percent of total time). If the line voltage is low and schedule is maintained, the period of coasting will be reduced and may entirely disappear. Therefore, in addition to the increase of current to give normal power which results from low voltage, the motors will be taking current for a longer period and the heating of the motors will be increased. C.O.C.

770—**Effect of Frequency on Design of Induction Motor**—Why are the rings and bars on a squirrel-cage induction motor designed to operate on a 25 cycle circuit of heavier cross-section than those used on 60 cycle circuits? Would a 50 hp, 25 cycle induction motor need as heavy bars and rings as a 75 or 100 hp, 25 cycle motor? What would be the effect of using 60 cycle rings on a 25 cycle rotor? H.G.

Twenty-five cycle motors in general have a smaller number of poles than 60 cycle motors. As the current in any given section of the end rings is the total secondary current divided by two times the number of poles, it is obvious that with a smaller number of poles (everything else being equal) there will be a greater current in any given section of ring and consequently a ring of larger cross-section will be required. A 50 hp, 25 cycle motor would require heavier rings for example than a 100 hp, 60 cycle motor with the same number of poles (the increase in horse-power of the latter appearing mainly as an increase in operating speed) but whether or not the ring for the 25 cycle motor would be of heavier cross-section than for a 75 or 100 hp, 25 cycle motor would depend on the relation between a number of other features of the design, and the relation might vary under different conditions. Using 60 cycle rings on a 25 cycle motor would result, in general, in too much secondary resistance followed by too great "slip" or drop in speed at full load and perhaps undue heating. A.M.D.

771—**Rewinding of Arc Lamp Regulator**—We have a moving picture arc regulator consisting of two reactance coils, one with stationary laminated core and the other core hung in the coil balanced by a weight. The coils are each wound with ten pounds or 115 turns of No. 6 wire and the cores are each 2x2x7 in. The arc takes about 30 amp. and 32 volts at the carbons. The lighting circuit was formerly 110 volts, 133 cycles alternating-current, but is now 110 volts, 60 cycles. When the change was made the coils began to heat and soon burned out. How should it be rewound for 60 cycle current? L.E.B.

The arrangement referred to is evidently that of a reactance coil in series with the arc across a 110 volt circuit. The reactance coil simply takes care of the difference between the arc voltage of 32 volts and the circuit voltage of 110 volts. If a reactance coil is to maintain a constant reactance voltage at various frequencies, the current through the coil must vary inversely as the frequency. When the frequency was reduced from 133 cycles to 60 cycles in the above example or in the ratio of about 2.2 to 1 there must have been a corresponding increase in current, which will account for the coil burning out. If it is desired to keep the current at normal when the frequency is thus reduced, the number of turns should be increased in the proportion of 1 to 2.2. It is doubtful if it will be possible to get so many extra turns on the old cores, if they were as closely designed on the 133 cycle basis as is usual with this class of apparatus. Probably the cores will have to be made larger. If the coils ran very cool on 133 cycles with 30 amperes through them it may be possible to reduce the wire

by one size when rewinding but this does not appear promising, as a No. 6 wire is none too liberal for 30 amperes. A.F.E.

772—Effect of Ageing of Iron on Exciting Current Required—What effect would the ageing of the iron in field and armature cores of an alternator have on the amount of excitation required? Is the heating of field cores brought about by the iron losses in the field or is it due partly to the armature current? (Alternator.) If not are these iron losses supplied by the exciting current. J.C.B.

Generally speaking, the ageing of iron in field and armature cores of an alternator would have no appreciable effect upon the excitation required. The air gap of the machine requires most of the magnetomotive force of the field winding and since the reluctance of the gap is independent of the ageing a large percentage change in the reluctance of the iron parts of the magnetic circuit will have little or no effect upon the total reluctance and field excitation required. The heating of the field cores of an alternator is caused both by copper and iron losses in the machine. The copper loss in the field coils warms the field iron by conduction. There are iron losses in the pole faces caused by the flux pulsations due to the passing armature teeth. This pole face loss is conducted back into the poles. In certain designs with small air gap and relatively large and open armature slots this loss has a marked effect on the field heating. The armature usually operates at a higher temperature than the field and therefore may supply heat to the field by radiation in the gap and by currents of air which carry the heat from armature to field. The heat in the armature is caused by the copper loss in the winding and the armature iron losses (see No. 147, Sept., 1908). All of the losses which heat the field cores except the field copper loss are supplied by the prime mover. The copper loss in the field coils is supplied from the exciter bus if separately excited. F.W.C.

773—Three-Phase Versus Two-Phase Power-Factor Meter—Is there any difference between a three-phase and a two-phase power factor meter? I recently saw a three phase meter connected to a two phase circuit; at least it was so marked on the dial. P.L.

Power factor meters for three-phase circuits will not be correct on two-phase or vice versa. It will be appreciated that at 100 percent power factor, for example, the voltage of a three-phase circuit and the current as well in the three lines bear a 120 degree relation to one another, whereas in a two-phase circuit under the same conditions, both the voltages and the currents in the line bear a 90 degree relation. Accordingly the impossibility of interchanging power-factor meters will be obvious from this consideration. F.M.

774—Method of Distinguishing Re-Entrant Armature Winding—According to various books, the term "reëntrant armature winding" is used to indicate different arrangements, depending upon the authority, for example, in "Dynamo-Electric Machinery" by S. P. Thompson, the definition of doubly reëntrant winding is, one consisting of only one circuit, but with this circuit so arranged that, in order to trace out all of the coils and segments, it is necessary to encircle the armature twice. According to later works on armature windings, a doubly reëntrant winding consists of two entirely separate windings insulated from one another. What is the generally accepted definition? Please give any other information on the subject which will aid in distinguishing such windings. B.W.

The term "doubly reëntrant" armature winding is usually understood to mean a winding that consists of two entirely separated windings. The use of the word "reëntrant," however, may easily cause misunderstandings. It is better to distinguish the armature windings according to the number of separate windings comprising them, e.g., by speaking of a singly-closed winding (1 winding), doubly-closed (2 windings), triply-closed (3 windings), etc. Series-parallel windings, i.e., two or more series windings that are connected in parallel may be singly closed or multiply-closed. The number of closings is given by the common divisor of the commutator pitch and the num-

ber of commutator bars and therefore must be smaller than half the number of circuits. If these have no common divisor the winding is singly-closed. For example, in an 8 pole machine, with 27 slots, 54 commutator bars, 4 conductors per slot, and a commutator pitch of 13, the two series windings are singly closed, forming one winding. In a 4 pole machine with 20 slots, 40 commutator bars, 4 conductors per slot, a commutator pitch of 18 (the winding consisting of 4 series windings), 40, 18 and 4 have the common divisor *2*, making the winding doubly-closed and thus consisting of two series windings of which each in turn consist of two other series windings, these two, however, forming one continuous winding. A.B.

775—Meter for Measuring Power-factor and Wattless Volt—Amperes—Please give information regarding use of alternating-current wattmeter for indicating or measuring either power-factor or wattless current or both, in an alternating current circuit. We have a wattless component meter on our switchboard, but no one at our power house seems to understand the principal of operation. We simply know that when the needle moves to the left it indicates that the other station is leading us, both stations operating in parallel on the power circuit. F.L.G.

A method of connecting two wattmeters on a polyphase circuit for measuring simultaneously the true watts and wattless volt-amperes is given in an article on "Meters Adapted to Special Uses" in the series on "Meter and Relay Connections" by Mr. H. W. Brown, in the JOURNAL for May, 1909, page 304, Figs. 8 and 10. Figs. 9, 11 and 12 of this article give connection for obtaining similar results with a single wattmeter and suitable switches for obtaining alternately the two equivalent connections on the single meter. With values of true and wattless components thus obtained the power-factor is given by the ratio "true watts $\div \sqrt{\text{true watts}^2 + \text{wattless volt amperes}^2}$."

776—Trouble with Controller for Elevator Motor—We have experienced considerable trouble due to sparking of the controllers installed in connection with elevator motors. The last contact of the rheostat shows serious burning due to the interruption of the circuit when the arm falls down. As a rule the fields are in circuit before the armature is connected, and the shunt field is apparently the last circuit to be opened; hence, it would appear that the trouble is due to the interruption of the shunt field circuit. Will you suggest a remedy. T.J.B.

From the description given, we would deduce that the apparatus was a semi-automatic controller in which the resistance is cut out by a contact arm moving across a series of contacts, the arm being operated by a magnet and its speed retarded by a dash-pot. The cause of burning may be attributed to two things, viz., the one mentioned, breaking the shunt field, and second that due to making the circuit with too low a starting resistance, thus causing a heavy rush of current on the first notch. As a remedy it will be found that a discharge resistance, connected around the shunt field, will stop the first cause and a resistance of approximately 600 to 700 ohms will probably be sufficient to do the work. This resistance should have capacity for continuous service. (We are assuming 220 volts, as this is the usual elevator voltage.) As a remedy for the second cause, the total resistance should be increased but we cannot say how much without knowing the present values of the resistance and more details regarding the actual controller connections. H.L.B.

777—Removing Oil from Carbons—Sometime ago we received a shipment of soft carbons of which about 200 were oil soaked. I would like to know whether you can suggest anything which could be done to remove the oil from the carbons. H.E.F.

Practically the only possible method to remove the oil from the carbons is to drive it out by heat. This will be greatly facilitated by first soaking the carbons in some solvent as gasoline or benzine for from forty-five minutes to an hour. In this way the heavy oil is easily removed from the carbons. The carbons can then be heated in a steam heated oven to about 95 degrees C. to drive out any of the gasoline in the pores of the carbons. This method is fairly inexpensive and will not cause any deterioration of the carbon. B.D.

PERSONALS

Prof. A. F. Nesbit has recently become connected with the Research Department of the University of Pittsburgh, where his immediate work will be in connection with the smoke problem. Prof. Nesbit was in charge of the department of physics and electricity at the New Hampshire State College, Durham, N. H., from 1895 to 1912. During the last several months, previous to taking up his present position, Prof. Nesbit has been in the general engineering department of the Westinghouse Electric & Mfg. Company at East Pittsburgh.

Mr. L. F. Howard has recently been appointed chief engineer of the Union Switch & Signal Company, Swissvale, Pa.

Mr. L. S. Boggs, superintendent of electrical construction of the New York, New Haven & Hartford Railroad, has resigned to accept the position of general manager of the Macon Railway & Light Company, with headquarters at Macon, Ga.

Mr. L. L. Nunn, who organized the pioneer Telluride Power Company and served as its general manager since its inception and as its president since 1910, will hereafter devote his time to the Beaver River Power Company, which supplies energy from a plant in Malad Valley to mines at Newhouse and Frisco, Utah.

Messrs. Charles F. Uebelocker, Charles N. Black and William von Phul have been admitted to partnership in the engineering firm of Ford, Bacon & Davis, 115 Broadway, New York City.

Mr. W. H. Cadwallader has been appointed assistant general manager of the Union Switch & Signal Company, Swissvale, Pa.

Mr. Charles M. Masson, one of the charter members of The Electric Club of Pittsburgh, is now employed as illuminating engineer of the Southern California Edison Company. This company is carrying on a campaign of education among its consumers and offering them free engineering advice to enable them to have economical and efficient lighting.

Mr. H. S. G. Hurlbutt, electrical engineer for the Esmeralda Power Company and Tonapah Mining Company, Tonapah, Nevada, has resigned to accept the position of superintendent of the Pacific Power Company at Jordan, California. Mr. Hurlbutt was formerly on the engineering apprenticeship course of the Westinghouse Electric & Mfg. Company at East Pittsburgh.

Mr. H. G. Knoderer, recently of the Columbus district office of the Westinghouse Electric & Mfg. Company, is now with the Robbins Electric Company, of Pittsburgh, as sales manager. This company has recently been reorganized, and is taking up an active campaign for increased business.

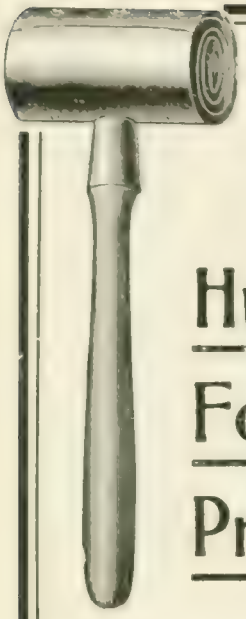
The *Industrial World* of Pittsburgh in its issue for August 5, contains a reprint of the article by Mr. E. M. Wise, on "Motor-operated Roll Lathes," from the JOURNAL for July.

OBITUARY

Mr. J. L. Davis, desiging engineer in the railway engineering department of the Westinghouse Electric & Mfg. Company, died very suddenly on August 8. Mr. Davis graduated from the University of South Carolina in 1897, and from 1897 to 1900 was professor of physics at the Bingham Academy High School in North Carolina. From 1900 to 1904 he was engaged in engineering work with the General Electric Company. In 1904 he entered the employ of the Westinghouse Company and for several years had charge of the design of direct-current railway motors, during which time many important designs were produced, among which was that of the motors used on the Pennsylvania locomotives at New York City.

ILLUMINATING ENGINEERING SOCIETY CONVENTION

The sixth annual convention of the Illuminating Engineering Society is to be held at the Hotel Clifton, Niagara Falls, Ontario, September 16-19. Among the list of some 21 items in the program are the following papers: "Recent Developments in Series Street Lighting," by Dr. C. P. Steinmetz; "Indirect and Semi-Indirect Illumination," by Mr. T. W. Rolph; "The Determination of Illumination Efficiency," by Mr. E. L. Elliott; "Steel Mill Lighting," by Mr. C. J. Mundo; "Research Methods," by Dr. E. P. Hyde.



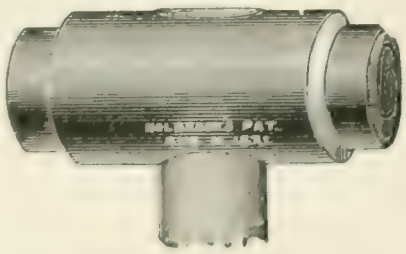
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Hide Faced Hammers
Raw Hide Mallets
Raw Hide Blanks for Gears

AMERICAN ELECTRIC RAILWAY ASSOCIATION CONVENTION

The thirty-first annual convention of the American Electric Railway Association is to be held in Chicago, October 7-11. There will be 20 convention sessions of the various subsidiary associations. The associations now have a membership of about 400 electric railway companies, and an individual membership of 1 550, in addition to which is the manufacturers' association including 350 of the leading manufacturing concerns. It is expected that the registration will be between 4 000 and 5 000.

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

The sixth congress of the International Association for Testing Materials will be held September 2-7, in the Engineering Societies Building, New York City. The technical proceedings will be unusually valuable. There are about 170 foreign and 35 American papers on the program. The proceedings will be conducted in English, American and French with the aid of interpreters. On Monday evening there will be a reception under the auspices of the American Society for Testing Materials, American Institute of Electrical Engineers, the American Society of Mechanical Engineers and the American Institute of Mining Engineers. Tuesday evening there will be a reception by the officials of the city in the New York Public Library. On Thursday evening a reception will be tendered the foreign members by the American Society of Civil Engineers. A special excursion trip to Washington, Pittsburgh and Niagara Falls for the benefit of visiting members will be made at the close of the Congress.

TRADE NOTE

The Speer Carbon Company has just installed a lot of new machinery to assist in supplying the demand for their motor and generator brush business, and now have the latest types of machinery for the manufacture of the highest grade brushes. Their testing department is right up-to-date, containing all the different apparatus for testing the co-efficient of friction, the breaking strength, voltage drops, hardness, and, in fact, all the latest devices for the testing of carbon brushes. The Speer Carbon Company to-day manufacture about 40 percent of all the motor and generator brushes used in the United States at this factory and have a large export trade which is growing rapidly.

WANTED

Agents in the Electrical and Mechanical Field

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THE ELECTRIC JOURNAL, Pittsburgh, Pa.

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A. I. E. E. COMMITTEES

At the last meting of the Board of Directors of the A. I. E. E., President Mershon announced the appointment of committees for the coming year. The following is a list of chairmen of these committees:

Executive, Mr. Ralph D. Mershon; Finance, Mr. Charles W. Stone; Library, Dr. Samuel Sheldon; Meetings and Papers, Mr. Walter S. Rugg; Editing, Mr. Lewis T. Robinson; Board of Examiners, Mr. H. S. Putnam; Sections, Mr. Paul M. Lincoln; Standards, Dr. A. E. Kennelly; Code, Mr. Farley Osgood; Law, Mr. Charles A. Terry; Railway, Mr. Frank J. Sprague; Educational, Professor H. H. Norris; High Tension Transmission, Mr. Percy H. Thomas; Electric Lighting, Mr. W. C. L. Eglin; Telegraphy and Telephony, Mr. S. G. McMeen; Electrochemical, Professor A. F. Ganz; Power Station, Mr. H. G. Stott; Electrophysics, Dr. John B. Whitehead; Public Policy, Mr. Calvert Townley; Historical Museum, Mr. T. C. Martin; U. S. National Committee of the International Electrotechnical Commission, Mr. C. O. Mailloux; Code of Principles of Professional Conduct, Mr. B. A. Behrend; Indexing Transactions, Mr. G. I. Rhodes; Relations of Consulting Engineers, Mr. Lewis B. Stillwell; Patent, Mr. B. J. Arnold; Sections Participation, Mr. E. A. Baldwin; Committee on Revision of Constitution, Mr. C. W. Stone; Membership, Mr. H. Clyde Snook; Badges, Mr. Charles W. Stone; Outgoing Presidents Testimonial, Mr. Walter S. Rugg; Joubert Memorial, Mr. C. O. Mailloux.

NEW BOOKS

"Strength of Materials" — Mansfield Merriman, 169 pages, 54 illustrations. Sixth edition. Published by John Wiley & Sons, New York City. Price, $1.00.

This is a secondary text-book for technical schools. A new chapter on combined stresses has been added. The discussion is devoted principally to moments of beams, columns or struts, torsion of shafts, elastic deformations, reinforced concrete, resilience of materials. No attempt is made to introduce calculus into the demonstrations but the results obtained are stated.

"The Human Factor in Works Management"—James Hartness. 159 pages. Published by the McGraw-Hill Book Company, New York City. Price, $1.50.

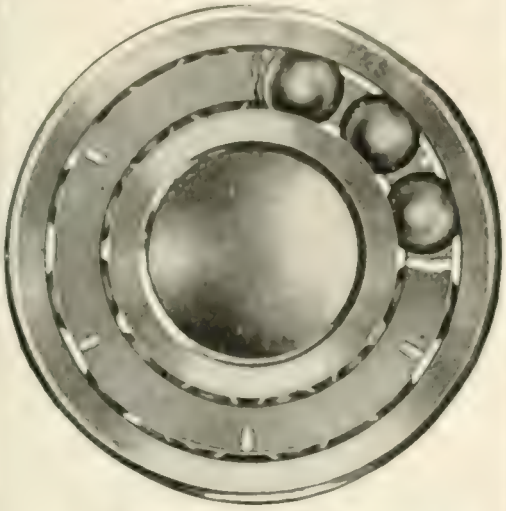
Among over 300 books which have appeared on the subject of Scientific Management, the majority deal with motion studies, cost systems, methods of supervising production, systems of compensation, etc. The present work, by the president of one of the large machine manufacturing concerns, appears somewhat radical. It seems to indicate that many of the revolutionary changes advocated by efficiency experts are undesirable. He preaches the superiority of existing things—things that may not be perfect but are nevertheless best. He places much stress on the inertia of mind and body. "The man who is doing the real work in the world is not the so-called progressive. He is one who points out better methods which may easily be established by a gradual change of old habits for new ones." "The best use of the present means, is a policy that should be given first place in all schemes of industrial management." The calling attention to the laws of habit and human inertia is certainly timely and should have a modifying effect on extreme progressiveness. The human element is one that has been all too much overlooked in plans for scientific management.

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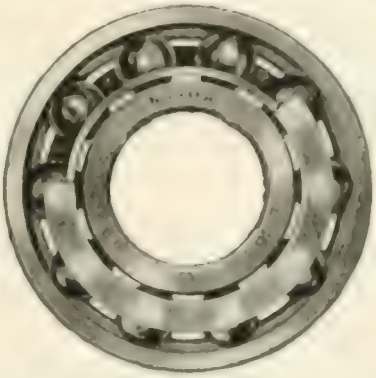


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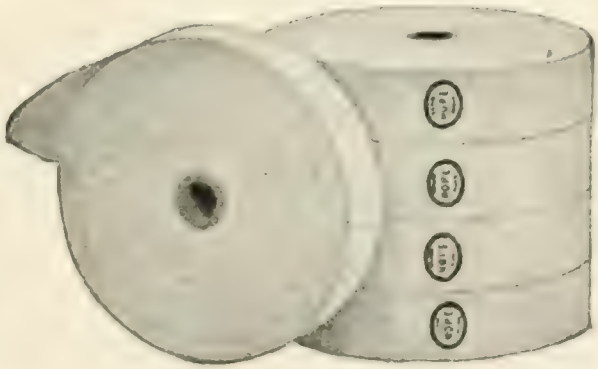
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NEW BOOKS

"Commercial Engineering for Central Stations"—Arthur Williams and Edmund F. Tweedy, 142 pages, 27 illustrations. Published by McGraw-Hill Company, New York City. Price, $2.50.

Central stations were first installed to supply current for lighting but soon extended their scope to provide power for driving small machines. Developments in the art of artificial illumination and motor applications have been most marked within recent years and the electrical utility companies have industriously followed the march of progress along these lines. There are other possibilities for broadening the field of the central station which have so far been exploited in a rather limited way. It is these new lines of attack to which the authors have devoted most of this instructive publication. Considerable data of interest on actual cost of operation of steam generating stations have been included. The subjects embraced are set forth in very good style, and the character of the book is well expressed, by the following headings of its different chapters. I—Estimating the amount of coal required to heat a modern city building. II—Cooling the air of buildings by mechanical refrigeration. III—Mechanical refrigeration for the cold storage of furs and fabrics. IV—The application of mechanical refrigeration to ice cream making. V—Cost of generating electrical energy in steam driven stations of small and medium size. VI—Kilowatt-hour costs in steam driven generating plants. VII—Central station load factors. VIII—Electricity in the modern department store. IX—Passenger elevators in office building service. X—The production and utilization of ozone. XI—The use of electricity for the disinfection of sewage. E.D.D.

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NEW BOOKS

"The Electric Circuit"—V. Karapetoff. 220 pages. Second edition published by the McGraw-Hill Co., New York City. Price, $2.00.

The first edition of this work was published as a pamphlet under date of August, 1910. In its present form the topics are treated somewhat more in detail, resulting in a larger book. New headings are included as follows: The resistance of conductors of various cross-sections, the electrical relations in polyphase systems, the performance characteristics of transmission lines, transformers and induction motors, and the permittance of transmission lines. This book as well as the companion volume, "The Magnetic Circuit," is intended primarily for text-book work. Problems appear at the chapter ends to be used by the student in order to acquire the assurance that a clear understanding has been secured of the underlying principles. Very few diagrams are given and very little numerical data coefficients or standards. A short chapter is devoted to an explanation of the use of complex quantities.

"Toll Telephone Practice." J. Bernhard Thiess and Guy A. Joy. 420 pages, 268 illustrations. Published by D. Van Nostrand Company, New York City. Price $3.50.

The developments in telephone engineering, like many other branches in engineering work, have become so extensive that no one treatise can hope to cover the subject satisfactorily. The authors have chosen a certain portion of telephone practice and prepared a very high grade book going sufficiently into detail to furnish practical assistance to those who wish to specialize on this subject. Beginning with the simpler rural telephone equipments the subject is developed quite logically. Many diagrams of telephone connections are given to illustrate the different arrangements which have been used or suggested. One chapter which does not apply exclusively to toll work is that on line construction. A liberal discussion on cross-talk and other inductive disturbances is included with diagrams showing various transposition combinations. The final chapter is devoted to the telephone repeater.

"Primer of Scientific Management." Frank B. Gilbreth. 108 pages. Published by D. Van Nostrand Co. Price $1.00.

As the result of a series of articles in the "American Magazine" on "The Principles of Scientific Management" by Fredrick W. Taylor, many letters were received with requests for detailed information. These letters were turned over to Mr. Gilbreth to answer. The present work is published entirely in question and answer form and is based on the original questions and answers which were received in the way just indicated. An introduction by Mr. Louis D. Brandeis is included.

"The Design of Static Transformers" —H. M. Hobart. 174 pages, 102 illustrations. Published by D. Van Nostrand Company, New York City. Price, $2.00.

While a comparatively small book, the work presents an excellent idea of the fundamental principles of practical designing. The reader is referred to certain standard treaties for underlying principles. The author being of British acquaintanceship, the work savors somewhat of English and continental practice.



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THE
ELECTRIC JOURNAL

Vol. IX OCTOBER, 1912 No. 10

Recent Electric Railway Progress

No one, who has observed the events of the railway world during the past year, can have failed to see the rapid development in every line. Apparently, every man connected with electric railways has been alive to the situation and has added his mite to make up an astonishingly large total of improvements. Only a few of the high spots are touched in this issue of the JOURNAL, but they are among the most important. The low floor car, with its great seating capacity and easy entrance and exit, has changed the discontented Pittsburgh "strap hanger" into a comfortably seated patron. The "stepless car" has filled a long felt want in New York. The double decked cars, both in Pittsburgh and New York, are further developments that are hailed with joy by the traveling public, and will undoubtedly be widely used. It is somewhat surprising that so many years have elapsed before the American railways have really given serious attention to the double decked car, which has all along been satisfactorily used in Europe. The explanation is probably in the fact that the European type of car would not meet American conditions. Apparently, there have been obstacles in the way of the double decked car for this country, which have prevented its use, until the developments which are contained in both the Pittsburgh and New York double decked cars have been made. The center of gravity of these cars is surprisingly low, and the roof of the car is also low by reason of the ingenious arrangement of the seats on the two floors and the low ground floor. The rapid acceleration and braking usual in this country will be a severe test on the superstructure of these cars. No weakness should develop in them, however, since the conditions are so well understood at this time.

The new cars have naturally involved complete re-design of trucks as well as motors and control equipment. All requirements, however, appear to have been met in an entirely satisfactory manner.

The new types of cars show that the comfort of the public is receiving most careful attention, but this has not caused the designers to forget the importance of economy of operation. The weights of the cars and equipments are reduced to the lowest limit consistent with good design, and the equipments adopted for them, consisting of motors with field control and the light-weight multiple-unit equipment are qualified to give the maximum efficiency in operation.

It is interesting to note the great progress made in the introduction of field control for railway motors, and the prediction is freely made that it is only a question of a very short time until everyone will demand it for new equipments. The additional complication is negligible and the saving of five to fifteen percent in power consumption in city cars and the advantage of using the same equipments for both local and limited service on interurban lines is sure to be appreciated. It must be understood, however, that field control must be applied with a full knowledge of all conditions involved, or the expected saving may not appear.

There is no doubt that multiple-unit control is making rapid strides in city service. Its advantage is more and more appreciated by the operating companies, and the demand for it is resulting in many improvements in the control itself, in the reduction in weight and in the simplification of the apparatus. The reduction in cost of damage suits resulting from getting the controllers off the platform, and the increased number of cars that can be operated on a street, due to operating them in trains, will both be strong factors in the ultimate substitution of multiple-unit control for the present almost universal use of hand control on city cars.

Turning to railway electrification, we find a steady progress made in the development of both the high voltage direct-current and the single-phase systems. Equipments have been in successful operation for some months at 1500 volts direct current, and one railway is to be electrified with 2400 volts direct current. The result of this will be awaited with great interest. The New York, New Haven & Hartford electrification is, of course, the largest railway electrification scheme that is under way, and it is understood that the operation of the new straight single-phase locomotives in use there, will be a much better index as to what the single-phase system really can do, than were the original locomotives built five or six years ago, which operate on both direct and alternating current. The use of the twin motors on the locomotive described in Mr.

Webster's article, has met with great success, and all of the claims that were made for it have shown themselves to be fully justified.

The opening of the New York, Westchester & Boston Railway to service, has demonstrated what the single-phase equipments can do in high speed, heavy, suburban service.

Great interest is now evident in overhead line construction, and the different types which are now in service should soon furnish sufficient data to permit a degree of standardization to be effected which has never yet been possible.

Altogether, the developments in the past year have been very important and show a most satisfactory condition of affairs; and, judging from the present activity, the next year will see even greater improvements.

N. W. STORER

The Pittsburgh Low Step Car

The article by Messrs. Welsh and Phillips, describing the low step type of car in service on the Pittsburgh Railways, is of considerable interest and value, as it marks a radical departure in car-truck and motor design. During the short time in which it has been in service, this car has demonstrated that, as a vehicle for the transportation of passengers in a congested city with grades and other difficult operating problems such as exist in the city of Pittsburgh, it surpasses anything that has been designed to date.

Primarily, the objects of such designs are,—first, the comfort and expeditious ingress and egress of passengers; second, increased number of passengers accommodated per car movement, due to increased seating capacity, and third, economy in power consumption secured through material reduction in weight.

Observation of the car in service makes it evident that all of these desirable features have been secured, perhaps even beyond the expectation of its designers. Furthermore, it is such a well balanced and easy riding car that it conveys the sensation that the car is gliding along, it rolls so smoothly and noiselessly. This feature not only adds materially to the comfort of passengers, but the reduction in track maintenance, as well as truck and motor maintenance, with the general use of cars of this type will undoubtedly represent a saving of thousands of dollars annually.

M. B. LAMBERT

Status of Automatic Signaling on Interurban Electric Roads

About two years ago there was a series of wrecks on trolley roads where the loss of life was so appalling that much attention was attracted, and the prophecy was freely made that there would be a great wave of signaling on trolley roads inside of a very short time. This prophecy has not been realized, probably to the ultimate advantage of both the roads and the public. This lack of haste has not been due to a want of appreciation of the importance of signaling on the part of the electric roads. On the contrary, they have been manifesting a very lively interest in railroad signaling as adapted to their conditions, and since February, 1911, their National Association has had committees studying the subject with the object, not only of puttting before the members a record of what *has* been done, but of stating what is recognized as good practice and recommending standards.

The Association has been particularly fortunate in the personnel of the committees appointed to work on the subject, as they have comprised not only men who are expert in the management and operation of trolley roads, but men who are expert in signaling practice as it exists on steam and heavy electric traction roads. The coöperation between the engineers and operating men, as evidenced by the joint meetings of the respective branches of the Association for discussion of the subject, also presages well for the future.

The interest manifested has also taken concrete form in a few installations, only one of which, i. e., that of the Illinois Traction System, is noteworthy in the percentage of the system signaled. Due partly to the differences of conditions existing on the different roads and partly to the results of the studies made to provide adequate protection with minimum cost, the installations have differed more or less, not only in the apparatus but in the schemes of signaling and circuits used. In this connection might be mentioned the development of light signals, arrestive even in bright sunlight at something over maximum braking distance; also the development of a system of single track signaling giving complete protection without preliminaries and a system of signaling called "Absolute-Permissive."

The signaling of electric roads (other than the heavy electric class), which was so forcibly brought to the attention of their managements some two years ago, and by the call for legislative

action, involved many important considerations. The financial one was, and is, almost without exception, the most serious. Next in importance was the lack of familiarity of the majority of the officials and operating men with the apparatus and systems available which could give them adequate protection, and the fact that there was at that time only one signaling system, i. e., on part of the lines of the Beebe Syndicate, from which they could make deductions applying to their own conditions.

Trolley contact systems are not included in the above statement, because it is becoming the general concensus of opinion that while they have a useful field as indicators of the occupancy of a section of track where conditions are such that it is not necessary to depend on them to prevent collisions, they are not otherwise suitable for automatic block signaling.

By next spring sufficient operating data from which to draw conclusions will be available from the installations now in operation, and standards will have been decided upon, or at least discussed, to an extent sufficient to have reduced the main problem of signaling to that of financing.

L. FREDERIC HOWARD

ELECTRICITY ON RAILROADS*

E. M. HERR

IT IS a rather curious fact that the steam railroad, the industry which has made the greatest progress in the last fifty years, and has done the most to advance civilization, has thus far benefited least by the development of electricity. When the really marvelous adaptation of the modern steam locomotive to the work of transportation under the extremely varying conditions of railroading met with in the world to-day is considered, it is quickly seen that very difficult conditions must be met by any kind of motive power ambitious to supplant it. Having received my early training in the motive power department of a railroad, and spent sixteen years in that and the operating department, I fully appreciate the conditions to be met and have no hesitation in saying that the field of applied electricity has as yet nothing to offer as a substitute for the steam locomotive in all its applications. I have also no hesitation in saying that although the steam railroads have thus far benefited less than almost any of our great industries by the development of electricity, it is certain that before many years they will, as a whole, be greater users of electricity and electrical appliances than any other industrial class. This being the case, I require no apology for presenting some thoughts on this subject to such a body of potential electrical users.

In the beginning of electrical development its use was as an illuminant; the dynamo was connected by belting to a convenient reciprocating steam engine, often in some plant where the engine was used for other purposes during the working hours of the day. The dynamos, or generators, were small, inefficiently belted to the engine, and operated in a way that still further reduced the efficiency of the plant. They were only run a few hours per day, standing idle except when electric light was required.

Next, larger, better designed generators were produced; the belting was omitted and direct connection to a more efficient steam engine resulted, with the engine often made compound and, where water was available, condensing. Later, the steam turbine, with its lower first cost, much lower installation cost, higher speed, and greater economy made its advent. It was still the practice for each large user of electric power to install his own generating

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*From an address delivered at the Railway Guild Dinner, May 14, 1912

plant, which necessarily was run with a load seldom requiring the full capacity of the engine and generator, and therefore rarely under conditions of maximum efficiency. In fact these installations much of the time ran at one-half, one-third, or even quarter load or less, and were nearly always shut down entirely for some portion of the 24 hours; in other words, the load factor of the station was extremely bad.

As the impossibility of a good load factor without diversity of load was better understood, the smaller stations became consolidated into larger power plants, furnishing not electricity for light alone or for power used in some special way, but for light and power used in as many ways and with as wide a spread as possible during the 24 hours. This diversity of load resulting in a high load factor is now being given great attention, and most wonderful improvements in the cost of producing electricity are obtained. The load factor influences enormously the cost of power —thus a plant having a load factor of one-quarter (a condition better than is often met with in a power house supplying power for a single purpose) has a cost per kilowatt-hour about twice as great as would be the case were the load factor from 60 to 70 percent, a condition not at all impossible with a sufficiently diversified load.

The importance and economy of a diversified load are fast causing a concentration of electrical power plants into enormous installations of great centralized plants, so located as to distribute power over large areas at a minimum cost, resulting also in a material conservation of our coal supply, estimated by Mr. Insull, president of the Commonwealth Edison Company, of Chicago, at upwards of 200 000 000 tons per annum, if the generation of energy for the different communities were concentrated in a few favorable localities. I quote further from a paper recently read by Mr. Insull, before the American Institute of Electrical Engineers:—

"The concentration of the production of energy for all purposes required in a given area of population would result in such a saving of capital and operating expenses as to provide for the generating, equipment, and primary transmission systems necessary to electrify the terminal systems and suburban service of all the trunk lines centering in and around any large center of population, and particularly Greater New York."

Mr. Insull further estimates that by operating the power systems in Greater New York as a unit rather than separately, operating expenses would be reduced by $1 000 000 per year, and taking into account fixed charges, depreciation, and interest, the change would result in the creation of about $60 000 000 in value.

How does the development of these great modern central power plants affect the railroads? I have already said that electricity has as yet nothing to supplant generally the steam locomotive. This does not mean, however, that the electric locomotive has no place on a steam railroad, or that there are no conditions under which the steam locomotive can advantageously be displaced by the electric locomotive. There are, under present conditions, a number of such, and when the steam railroads furnish (as they themselves will ultimately) a great load to the modern centralized power plant which will modify and so greatly improve the load factor and costs of producing power by these great plants they will obtain such low costs and great reliability of power that the field for the advantageous use of the electric locomotive will be enormously extended. The rapidly increasing requirements for more and more powerful locomotives, adapted to the rapid and continuous movement of heavier trains, and the demand that such locomotives, while enormously powerful, shall be easier on rails and roadbed than far less powerful and less efficient steam locomotives (a condition met by the operation of several electric locomotives by one man through the system of multiple-unit control) will still further add to the opportunity for the advantageous use of this new power in the transportation field. The railroads will then buy electric power delivered on their lines instead of coal, and be saved the large capital expenditure required for the installation of power plants.

One place already occupied by the electric locomotive is in the terminals in large cities. Here, as in many other places, where the application of electricity is highly advantageous, it was not at first the economies of first cost or lower operating cost that brought about the change to electric power. The electric locomotive was first used in terminal work because of the nuisance and discomfort of steam power to passengers and others, and the change was made by legal enactment regardless of economy. Like many other enforced changes, so many benefits, not at first apparent, have developed that it is fast becoming evident, that the incidental advantages are so many and so great that in the future no other means

of operating a great terminal in a large center of population will, from even purely economic conditions, be considered.

Thus, in a large city it is now possible by using electric locomotives to establish a great railway terminal in the very center of population without annoyance or discomfort to the neighboring people, and with practically no loss of the very valuable land for building purposes, without regard to the kind of buildings to be erected, excepting that the terminal shall occupy the basement, or, if desired, the sub-basement. So clean, noiseless and adaptable is an electrified terminal that the occupants of the building erected over it know of its existence only by seeing the ebb and flow of the tide of humanity going and coming by its trains. Again, the electric locomotive enables the capacity of a terminal to be greatly increased owing to the greater rapidity of its movement over that of a steam locomotive, and the fact that the electric locomotive does not have to be turned, coaled, watered, have fires cleaned nor its boiler washed. This also reduces the locomotive equipment needed for a given train service.

All these advantages of the use of the electric locomotive in the terminals of large cities may be conceded, but objections may still be made that the cost is so high as to be almost, if not quite, prohibitive. Let us consider this seemingly high cost. Why is it that electricity has almost entirely supplanted direct steam as a means of driving the machinery in shops, factories, and mills of all kinds, notwithstanding that the steam power plant can be installed for about $40 per horse-power, while from two to four times this amount per horse-power is required to supply the corresponding electric power plant? True it is, that notwithstanding the higher first cost there is a large saving in direct operation by electricity as compared with steam engines, but this is not the only, or indeed the chief reason for the change. The higher first cost is more largely justified by the possibilities which electricity gives of doing other and better work, and of obtaining results not in any way possible with steam power. When the railroads can buy electric power metered on their lines, at such points as they desire to use it, which will be furnished from large centralized power plants so arranged as to make failure of supply practically impossible and at a cost of but a fraction of the cost of power on a steam locomotive, then the use of the electric locomotive will be so widely and rapidly extended as is now not dreamed of, nor under present

conditions economically possible. So on railroads the advisability of electrification must stand or fall on not only the consideration of the relative economy, capital cost and operating cost both considered, but in addition to this, (and often more important) a proper judgment of what economies and results can be obtained by electricity that steam cannot accomplish. Thus the increased capacity of a given terminal, together with the utilization of valuable sites for buildings made possible only by electrification, may alone amply justify the increased cost.

In addition to the advantages mentioned above, in large terminals, the use of electricity on wharves, in freight houses and properly designed auto trucks for delivery of freight to consignees and collecting freight from shippers, must not be overlooked. On wharves, in freight houses and other places where freight is temporarily stored or stopped in its movement from one kind of carrier to another, electricity by its wonderful adaptability to subdivision and use in small or large motors is most advantageous. By a system of telpherage, properly designed and adapted, all kinds of freight can readily and economically be taken from car to freight house or wharf, or the reverse, and what is of very great importance, the entire space covered by this system can be economically used. The statement has been made that the cost of moving a ton of freight from the point at which it originates to the railroad car which is to carry it by rail to the railway terminal at its destination, added to the additional cost of delivering it from car to the consignee's store, factory, or warehouse, is as large as the entire charge for rail transportation for a large proportion of freight handled by rail which has to be delivered and collected by dray or truck. Why then should not the railroads themselves arrange to collect and deliver freight, especially package freight, at terminals? Here again electricity can be of great service in furnishing the power to drive the telpherage for loading and unloading cars and supplying the motive power of a fleet of auto trucks and drays so handled as to cause the minimum delay of freight cars at terminals and the promptest delivery of package freight at the lowest cost.

Several advantageous uses of electricity in railroad service have been suggested, and although no attempt has been made, or will be made to cover this field, for time forbids, there is one feature of this valuable agent in railroad service that must not be

omitted, because it is really but little understood or appreciated—this is the reliability of electricity when properly handled. I am safe in saying that there is no class of machinery to-day that can be designed so exactly to meet given conditions as electrical machinery. Think of the reliability and freedom from failure in the electrified transportation service in and about New York City. Centering here are the electrically-operated terminals of the two greatest railroad systems of the world, the train service on both of which, statistics show, is far less subject to interruption and delay since operated electrically than under the best results ever obtained by steam. This is creditable and reassuring but how much more remarkable and really marvellous are the results obtained in the operation of the subway and elevated railroads of this great city, both of which are operated with a headway of trains absolutely impossible of attainment with steam power, were its use otherwise possible, and with a regularity, precision and safety which is one of the wonders of this wonderful Age of Electricity.

It is really only about twenty years ago since the foresight and judgment of Mr. George Westinghouse caused him to predict and actively begin the wonderful development in the use of the alternating current, and by so doing to call down upon himself a storm of criticism from many of those then foremost in electrical development which might easily have deterred a less courageous spirit. He, through his company, persisted in the development and exploitation of this system, sure of its possibilities, and was quickly followed by all the others in the field of electrical engineering and manufacture, for it was seen to be the real foundation upon which the future development of all electrical progress was to be made. Without the alternating current the long distance transmission of power would be impracticable and the use of electricity for transportation of passengers and freight on railways impossible.

Again, in a notable address before the Institute of Mechanical Engineers of Great Britain, Mr. Westinghouse was the first to call attention to the importance of the adoption of standards and uniform methods in the development of railroad electrification. The necessity for this is obvious, under the conditions of general interchange of traffic universal in American railway practice, and especially in the joint use of terminals by several lines, and the routing of passenger cars through and over several connecting lines. The task of determining these standards is one of great difficulty

and complexity, and can only be successfully carried out by a commission selected and employed by a sufficient number of railroads who would accept the findings and conclusions of such a commission, and whom the other railroads interested would acknowledge to be entirely representative. The American Railway Association would seem to be the logical place to begin this great work.

Finally, let me impress upon you that there is no longer a question of whether electricity can do the work of broadening, extending, and improving the very admirable performance of the modern steam locomotive. This has been amply demonstrated. The question to be answered in any specific case proposed is purely the economic one of, will it pay. Electricity asks no consideration on any other basis, and would get none if it did. In determining this question of profit and loss, let me urge that no narrow view be taken but the real possibilities of this wonderful servant of civilized man be carefully and thoroughly weighed, and in order to do this that every railroad officer determine not that he will become an electrical expert, but that he will keep in touch with the more general and commercial features of electrical development as relates to railroading, for only by so doing will it be possible for him to pass intelligently upon the many recommendations which will come before him as one of the class of the greatest users of electricity and electrical appliances in the industrial world.

THE PIEDMONT & NORTHERN LINES

A RECENT 1500 VOLT DIRECT-CURRENT DEVELOPMENT

H. D. MURDOCK

THE Piedmont & Northern is not an interurban system such as found throughout the greater part of the country, but a railroad system with its own right-of-way, low grades, long radius curves, steel bridges, brick and concrete buildings, high power locomotives for freight service, high speed large capacity motor cars for express and passenger service; in fact, combining the light frequent service of the interurban with the great capacity of the steam railroad—a complete railroad system using electricity as its motive power.

A glance at Fig. 1 will show the magnitude of the system planned and under construction which approximates three hundred miles of main line. The Piedmont section which this road is to serve is a rich agricultural region producing large quantities of cotton and tobacco and other staple crops. It is in this section where the greatest development of the manufacture of cotton goods has taken place in the South. The cotton mills which are contributory to this road manufacture annually hundreds of millions of yards of cotton cloth, and employ tens of thousands of operators. While the manufacture of cotton goods is the leading industry of this section, the towns in the northern portion are largely engaged in the manufacture of furniture. High Point, N. C., is a close rival of Grand Rapids in the furniture industry. While this section will produce a very good passenger business, it is the freight traffic that will be the greatest revenue producer. A very complete scheme of

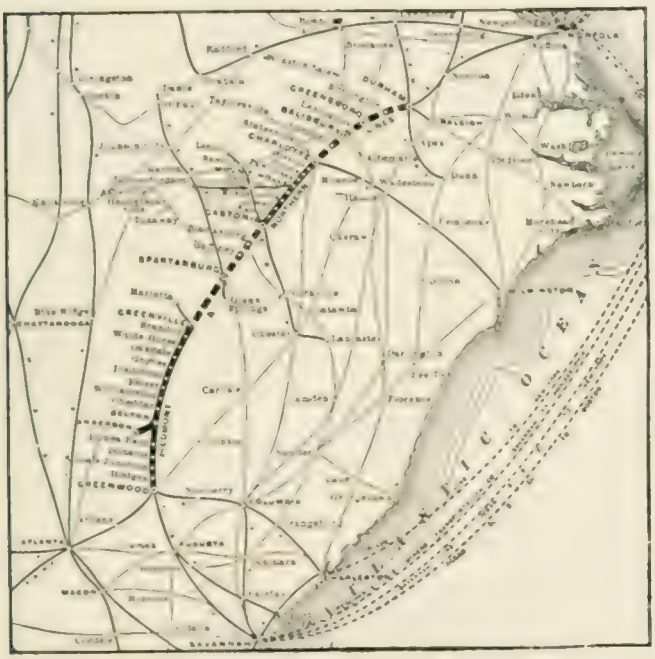


FIG. 1—MAP OF PIEDMONT SYSTEM

side tracks have been worked out for various industries along the line. Connections with the steam trunk lines have been made at advantageous points, for the interchange of traffic.

STATIONS AND BUILDINGS

A complete set of standard station designs has been worked out for the entire system. Fig. 2 shows the freight station at Char-



FIG. 2—CHARLOTTE FREIGHT STATION AND DIVISION OFFICE

lotte with division offices. A combined freight and passenger station is shown in Fig. 3. This station is located at Mt. Holly and is 104 feet long and 22 feet wide, and has two waiting rooms, an agent's



FIG. 3—PASSENGER AND FREIGHT STATION AT MT. HOLLY

office, and a baggage and freight room. These two general designs are used with standard modifications to meet the requirements of the various towns and cities. In the construction of these stations hard red brick is used in the walls up to the water table, and the

balance of the wall is built of unit cement brick; the roof is of red tile of the Orleans pattern. This unit cement brick is a standard building material with this Company and is used in all of its new buildings. This cement brick is made by pouring a mixture of Portland cement and crushed granite into an iron mold and curing the bricks in a kiln under a pressure of live steam. It is claimed that this method of manufacture produces a cement practically moisture and fire-proof and of great strength.

TRACKS AND BRIDGES

The tracks of this system are all on private right-of-way which has been carefully selected to avoid severe grades and curves. The highest grades do not exceed one percent and the sharpest curves six



FIG. 4—LONG CREEK BRIDGE

degrees. To secure these low grades and easy curves in a country which is generally hilly a great amount of grading has been done—over 1 000 000 yards of earth were handled in grading the first twenty mile section out of Charlotte. This section has required the most grading of any built up to date, however the estimates on the Greenville-Spartanburg section call for a greater amount of grading than the Charlotte-Gastonia section. Work on the Greenville-Spartanburg section is now under way.

The rails used weigh 80 pounds per yard and are of standard cross-section, and laid on white oak ties. The track is ballasted with fine gravel taken from the right-of-way. Electric welded rail bonds are used exclusively.

All bridges and viaducts have concrete abutments with steel

spans designed to carry the heaviest freight traffic with a large margin of safety. The bridge over the Catawba river at Mt. Holly is 570 feet long and 50 feet high; the highest bridge on the system is the one over the South Fork of the Catawba at McAdenville, which is 100 feet high and 460 feet long.

OVERHEAD CONSTRUCTION

The single catenary construction is used throughout the system. The trolley line consists of No. 0000 grooved hard-drawn copper wire and a 7-16 inch steel messenger cable. The trolley wire is suspended every 30 feet from the messenger by hangers. The brackets are of rolled steel of T cross-section and are placed so as to give a clearance of 21 feet, 6 inches between trolley wire and rail. The line poles are native chestnut, 35 feet in length with 8 inch tops, and are set 8 feet, 9 inches from centre of track. The poles are spaced 150 feet on tangents and on curves the spacing varies from 90 to 120 feet.

The insulators for supporting the messenger cable are tested for 17 000 volts; all guy and anchor wires are insulated with special



FIG. 5—FEEDER SYSTEM AND METHOD OF SECTIONALIZING

wood strain insulators. All feeders are No. 0000 equivalent aluminum and are carried on the same poles as the trolley. The feeders and trolley are sectionalized between sub-stations, as shown in Fig. 5 The middle disconnecting switch is located at a point where it can be operated by a station agent upon advice from the dispatcher. Under normal conditions all switches are closed.

Lightning arresters are installed at intervals of about one-half mile. They are provided with a special switch and fuse. The switch provides safety in making inspections and repairs, and the fuse protects the arrester in case of abnormal discharges.

The telephone lines are in duplicate and are carried on the line poles. All train dispatching is done by telephone. The selector system of ringing is used thus avoiding the confusion of code ringing. The system is used at all sidings by the means of a semaphore selector and telephone equipment which are mounted on the same iron post in a weatherproof box, making the apparatus self-con-

tained. The dispatcher can throw the semaphore to danger at any siding, the crew signaled calls the dispatcher and upon his advice clears the signal, thus giving the dispatcher means of blocking and getting into communication with any train on the road. Every train carries a portable telephone set with extension pole so that connections can be made at any point along the line.

SUB-STATIONS

All the power for the operation of the Piedmont & Northern lines is furnished by the Southern Power Company, with the exception of that for one 600 kilowatt sub-station at Anderson, S. C., which is supplied by a local power company. The high tension lines of the Southern Power Company cover the entire territory to be traversed by the lines of this railway system. Power is supplied



FIG. 6—SUB-STATION AT BELTON

for the present operations by ten 500 kilowatt synchronous motor-generator sets and one 600 kilowatt set driven by an induction motor. Each motor-generator set consists of a 720 horse-power, three-phase, 60 cycle, 2400 volt, 900 r.p.m. self-starting synchronous motor, having coupled to each end of its shaft a 250 kilowatt, 750 volt compound-wound commutating pole generator. A 6.5 kilowatt, 125 volt, exciter is direct connected by a flanged coupling to one of the 250 kilowatt generators. All four machines are mounted on a common bed-plate, thus making a very compact generating set. The two 750 volt direct-current generators are connected in series to deliver 1500 volts, which is the trolley voltage of this system. These generators have excellent commutating characteristics and will easily commutate 200 percent overloads. The synchronous motors are

started by the use of an oil immersed auto-starter switch—a special auto-transformer is used where the station transformers have no low voltage taps. The field of the motor is short-circuited through the exciter armature in starting. These sets can be started very quickly—they have been started from rest and 1500 volts put on the line in 35 seconds. Each substation is provided with a Tirrill regulator, which is designed to control the power-factor automatically by varying the voltage of the exciter and thus changing the field strength of the motor as required.

The switchboards are black finished marble mounted on angle-iron frame work. All switches and circuit breakers carrying 1500

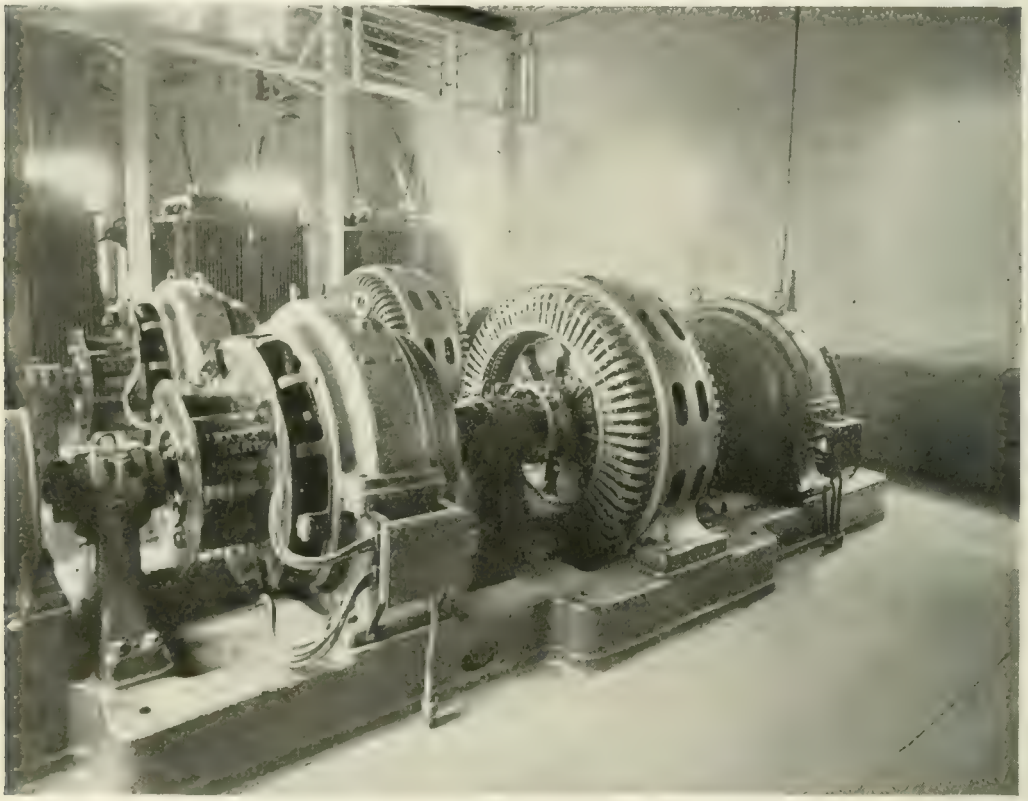


FIG. 7—INTERIOR VIEW OF BELTON SUB-STATION
Showing motor-generator sets and transformers.

volts are placed well out of the reach of operators and are connected to the operating handles by insulated rods. The only switches in normal reach of the operator are the 110 volt motor field switches.

The 1500 volt feeders are protected by electrolytic lightning arresters. These arresters are connected direct to ground and have a very small charging current flowing all the time.

The substations are located wherever possible in existing transformer stations of the Southern Power Company so that the 2400

volt current for the synchronous motors can be taken direct from their power distributing switchboard, and at the same time the entire power output can be placed in care of one set of operators. At points where the present transformer stations of the Southern Power Company would not give proper distribution of power, new stations have been built. The sub-stations along the line are placed from 15 to 25 miles apart to meet the varying traffic conditions and points of delivery of power by the high tension lines. So far sub-stations have been installed at Hoskins, Gastonia, Greenville, Belton, Anderson and Downs.

LOCOMOTIVES AND CARS

The present motive power equipment consists of six 55 ton

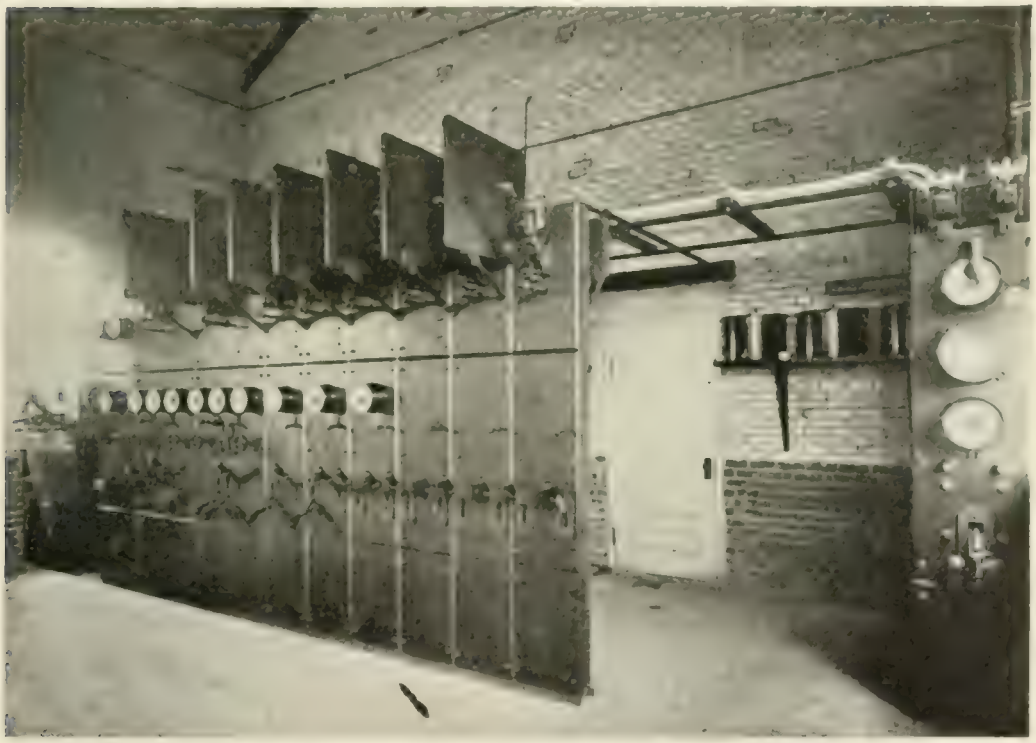


FIG. 8—INTERIOR VIEW OF BELTON SUB-STATION
Showing switchboard arrangement.

electric locomotives, 23 passenger motor cars and eight express motor cars.

Passenger Cars—The motor cars have a total seating capacity of 68 persons, and are 60 feet in length and nine feet, one inch wide. The cars are divided into four sections:—a baggage compartment, 9 feet, 8 inches long; a negro compartment, 8 feet; the main compartment, 25 feet; a smoking compartment, 11 feet, and a vestibule, 4 feet.

The interior of the cars is finished in selected mahogany, except the baggage compartment, which is finished in ash. The seats in the main and negro compartments are upholstered in plush, and those in the smoking compartments are upholstered in leather. In order to make the negro compartment, which is situated next the baggage section, accessible without passing through the main compartment, steps similar to those used on the rear platform have been provided for by using an ingenious combination trap door in connection with the sliding baggage-room door. The cars are heated by electric heaters which take current direct from the 1500 volt trolley.



FIG. 9—TWO CAR TRAIN AT CATAWBA RIVER BRIDGE

The passenger and express car equipments consist of four commutating pole motors rated at 110 horse-power at 750 volts. The gear ratio of the passenger cars is 23:54 and of the express cars 16:61. The weight of the motor is 4150 pounds. The armature of this motor is insulated for very high voltage. Mica has been largely used in insulating all conductors from ground and the clearance of all live parts to ground is greater than in ordinary practice. The passenger cars are designed for single-end operation. The general character of apparatus is about the same as for the locomotives, except that the number of switches is reduced on account of less capacity and smaller number of running points.

Express Cars—The eight cars of this type are 50 feet long, 9 feet 2 inches wide, and 13 feet 6 inches from rail to top of running board. The car, fully equipped, weighs 40 tons. These cars, as well as the passenger cars, are equipped with radial M.C.B. couplers so that they can be coupled to standard steam cars.

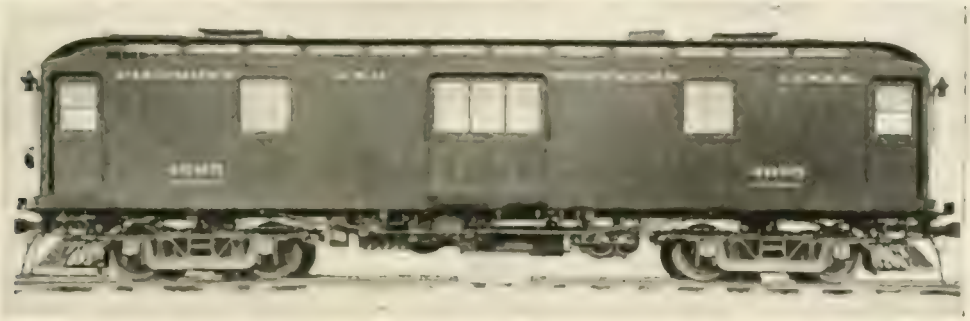


FIG. 10—EXPRESS AND BAGGAGE CAR

Locomotives—The locomotives are of the steeple cab type arranged for double-end operation and weigh 55 tons complete. The over-all length, face to face of couplers, is 35 feet, length of body 32 feet height from rail to top of cab 12 feet. They have two swivel trucks each 7 feet, 4 inch wheel base, while the total wheel base is 25 feet. The locomotives are equipped with four commutating pole



FIG. 11—LOCOMOTIVE AND FREIGHT TRAIN AT MT. HOLLY
Showing feeder sectionalizing switch.

motors, rated at 185 horse-power each at 750 volts. The motors are cooled by forced ventilation so that they have a large continuous capacity.

Forced ventilation for the main motors is obtained by mounting a blower on an extension of the dynamotor shaft. The dynamotor

is thus made to serve three separate purposes:—operating air compressor, furnishing 750 volt power for lights and control circuits, and forced ventilation for the motors. A considerable amount of space has been saved by this arrangement. As there is a dynamotor in each end of the locomotive a duplicate air and control current supply is provided and increased capacity for handling heavy trains. The total weight of the electrical equipment is approximately 37 000 pounds. The locomotive air brake equipment is the double-end type, with two compressors, each having a capacity of 35 cubic feet per minute.

The well known hand-operated unit switch control, which has been so successfully used on 600 volts equipments, has been modified to meet the requirements of the higher voltage used. These modifications are:—more switches in series, greater insulation dis-

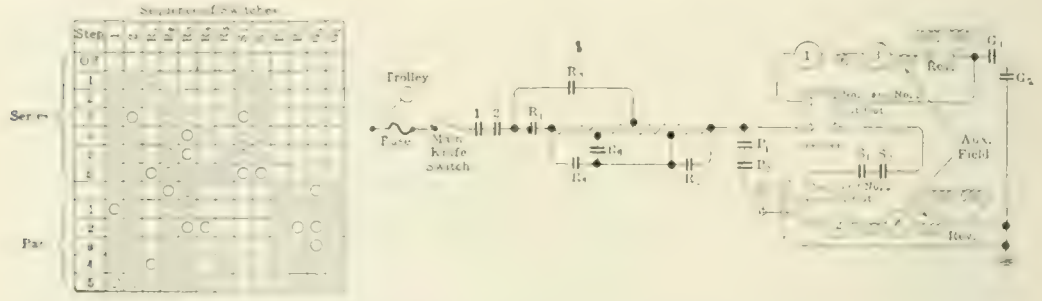


FIG. 12—SEQUENCE OF SWITCHES AND SCHEMATIC CONTROL DIAGRAM OF PASSENGER AND EXPRESS CARS

tances and creepage distances, more powerful blowout action to extinguish the high voltage arcs, and larger chambers for gas expansion, making the switch group slightly larger than for a corresponding 600 volt equipment. The positive opening of the switches by heavy springs, and the heavy constant contact pressure, irrespective of line voltage, due to the use of compressed air for actuating the unit switches, makes this type of control very satisfactory for high voltage work.

It will be seen from the main diagram for a motor car, Fig. 12, that the four motors are connected in pairs, the two motors of each pair being permanently connected in series, making two motors a unit in the matter of control. The line switches act as overload circuit breakers. A very liberal number of points has been provided on the locomotive controllers so that the motors can be worked close to the rail adhesion limit. The locomotives are provided with

train line "jumpers" so that two or more locomotives can be operated as one unit.

A dynamotor has been one of the special features of high voltage car equipments in the past and its use has been confined to furnishing current for lighting and control, and in many cases current for the air compressor motor. The dynamotor used on this equipment performs all of these functions and in addition operates the air compressor by means of a multiple disk clutch, thus eliminating the compressor motor.

The dynamotor armature has two separate windings on the same core, each connected to a commutator. Each armature wind-

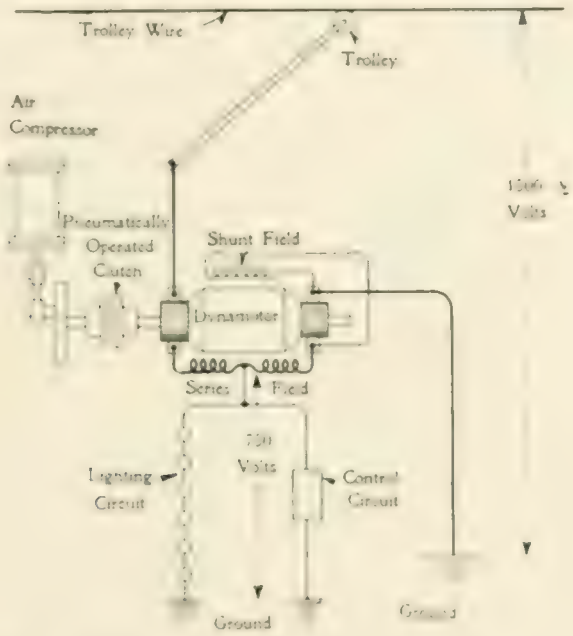


FIG. 13—DYNAMOTOR WIRING DIAGRAM

ing is in series with half the series field and these armatures and fields are in series with each other on 1 500 volts, thus giving a half voltage tap at a point between the two field windings, as shown in Fig. 13. A shunt field winding is connected across the low voltage armature to maintain the speed approximately constant. The speed on 750 volts is approximately the same as on 1500 volts, thereby maintaining the air compressor capacity on the lower voltage. The changer-over switch, Fig. 14, is held in the 1 500 volt position by a spring, so that if anything should happen to interrupt the supply of either the air or current controlling this switch it will return automatically to the high voltage position, which is safe for

both voltages. These dynamotors are rated at 13 kilowatts and, in addition to driving the compressors, furnish current for all lights and control. As the dynamotor runs continuously the compressor is connected to it by means of a multiple disk clutch, which is operated pneumatically by an air governor to cut the air compressor in and out as required.

The first 1200 volt or "high voltage" direct current railway installation in this country was that on the Indianapolis & Louisville Traction Company lines in Indiana which was put into regular

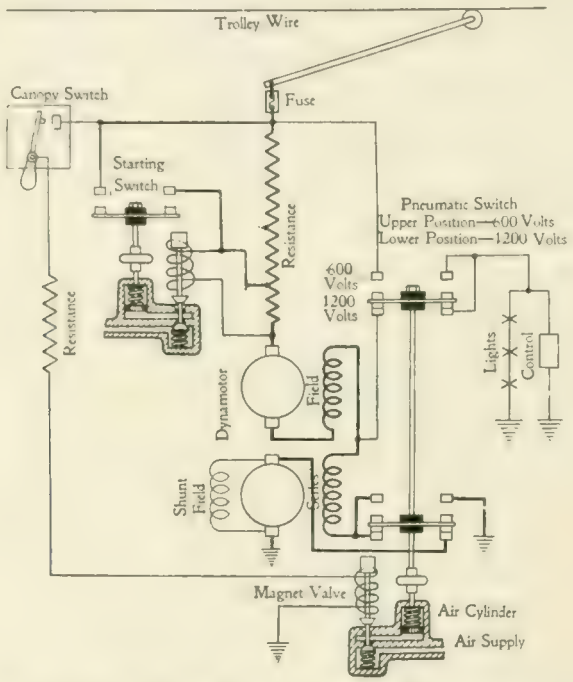


FIG. 14—WIRING DIAGRAM OF DYNAMOTOR CHANGE-OVER SWITCH

The dynamotor starting switch is governed by a time limit relay, which short-circuits the starting resistance after the dynamotor comes up to speed.

operation in October, 1907. This was a complete success from an operating standpoint and quite a number of successful installations have been made since. The Piedmont & Northern is the first road to operate at 1500 volts and now has 65 miles of road in operation. The performance of the equipment shows that 1500 volts is as easily handled as 1200 volts, and in fact has given no more trouble than 600 volts, which would seem to indicate that the limit of "high voltage" direct-current railway operation has not yet been reached.

THE PITTSBURGH LOW FLOOR CAR

J. W. Welsh, Electrical Engineer and E. R. Phillips, Supt. of Equipment
Pittsburgh Railways Company

IN the fall of 1910 the Pittsburgh Railways Company put into service a two-car train of exceptionally large seating capacity to accommodate the heavy traffic of the morning and evening rush hour periods. The novel feature of this train was the double-truck trailer, the general design of which is described below.

GENERAL FEATURES

While this car was first operated as a trailer, it was designed for use as a motor car, this depending upon the development of a small motor capable of operating on a wheel diameter of 22 or 24 inches. The special points in the design of the car body are:—the low floor, the center entrance and exit, the arrangement of seats continuously around the sides and ends of the car, a continuous floor from end to end of car, the absence of all bulk-heads or partitions within the car body and the absence of heavy platform knees.

The desirability of a low-floor car is obvious, as it makes entrance and exit much easier by reducing the number and height of steps. The absence of heavy platform knees results in a very light car. By means of the center entrance and exit, the average distance from the doors to the seats is greatly reduced. This shortens the time required for loading and unloading, and is an important factor in maintaining schedules, particularly in a car of large seating and standing capacity. Furthermore, there is less crowding in the aisles of the car since only half the people on the car use the aisle at each end of the car, instead of all using the same aisle as in the ordinary car. Another advantage is the rapid unloading during the rush hour in the terminal district by the simultaneous use of both entrance and exit doors for this purpose. As the conductor is stationed between both entrance and exit doors he can control their use according to the requirements of the service.

The seating arrangement secures a maximum seating capacity for a given length of car. This is in part due to the use of what would be the platform space at the ends of the car for seats and in part by the use of removable seats at the center of the car where the entrance and exit doors are located when the car is operated in the reverse direction. The actual number of seats secured can be increased in this car by changing the arrangement from longitud-

inal to cross seats, or by the use of an intermediate longitudinal seat in the center aisle.

The continuous low floor within the car body facilitates the movements of passengers and reduces the possibility of accidents.

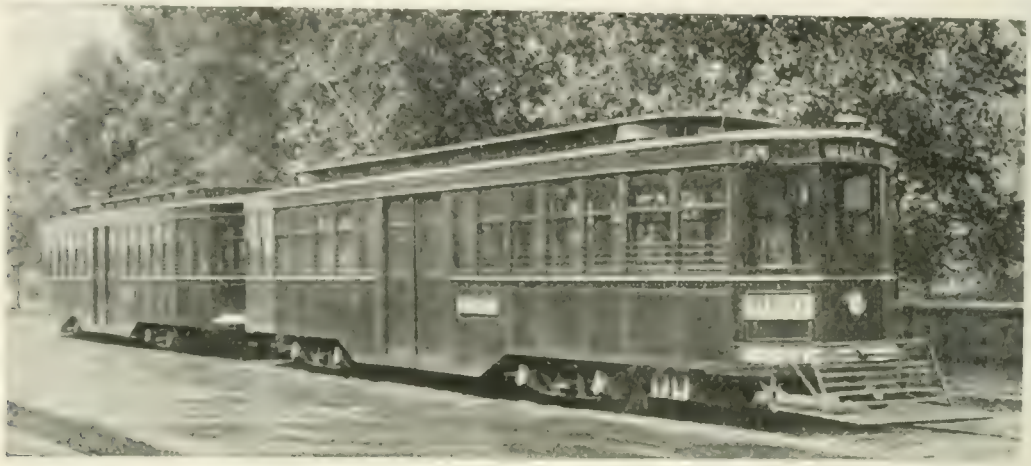


FIG. 1—GENERAL VIEW OF LOW FLOOR MOTOR CAR AND TRAILER

The work of both motorman and conductor is made more comfortable as they are at all times protected from the weather.

CONSTRUCTION OF CAR BODY

In the construction of the car, steel is the principal material, the only wooden parts being the roof framing, sash, doors and flooring. The sides of the car are constructed on the principal of a plate girder. The lower or tension member consists of a 3 by



FIG. 2—SIDE VIEW OF LOW FLOOR CAR
Showing center entrance and exit.

2½ by ⅜ inch rolled steel angle. The side sheathing consists of ¼ inch specially rolled open hearth steel plates and forms the web of the girder extending from the side sill to the belt rail. It is made in sections covering the space between two posts and at the joints ⅛ inch steel splice plates are used.

Special provision had to be made to accommodate the large opening for the center entrance and exit doors. This was secured by dropping and reinforcing the side sill angles under the doorway and providing a rolled steel channel header across the top of the doorway. A truss structure is thus formed consisting of this

TABLE I—GENERAL DIMENSIONS OF CAR BODY

Length over buffers	45 ft. 0 in.
Width at belt rail	8 ft. 2 in.
Height from rail to top of roof	10 ft. 6 in.
Height from rail to floor level	2 ft. 6 in.
Height from rail to bottom of side sill at door opening	12 in.
Height from rail to side sill at bolster	2 ft. 0 in.
Height from bottom of side sill to top of roof	8 ft. 6 in.
Center to center of bolsters	31 ft. 8 in.
Height from rail to top of side sill at center of opening	17 in.
Height from top of side sill at center opening to floor level	13 in.
Weight without equipment	14 000 lbs.

header above the door, the double posts at either side of the doorway and the depressed side sill below. The side sills are depressed for a suitable length to accommodate the pockets of the sliding doors, and the width of this depressed portion is just sufficient for the single step employed between the car level and the ground. The general dimensions of the car are given in Table I.

TRUCKS

The trucks of this car are noteworthy for their low height, compactness and absence of trimmings. Light weight was one of the chief ends sought for. In spite of the rigid simplicity characteristic of the design, the cars are notable for their easy riding qualities. There is furthermore no unusual jarring in going over special work,

TABLE II—GENERAL DIMENSIONS OF TRUCK

Wheel base	5 ft. 0 in.
Center to center of side frames	6 ft. 2 3/4 in.
Distance from rail to top of bolt cover plate (light car)	19 in.
Diameter of wheels	24 in.
Gauge of track	5 ft. 2 1/2 in.
Weight of truck with wheels and axles	4 220 lbs.

although it might be reasoned that a greater fall would occur in this case, owing to the smaller wheel diameter. As a matter of fact, however, the increase in this fall amounts to only 1/4 inch at a distance of three inches from the perpendicular line through the wheel center, when comparing a 34 inch wheel and 24 inch wheel.

As a result of lowering the center of gravity one foot, three inches by means of these trucks, there is a considerable reduction of the swaying motion as compared with the standard type of car. The truck construction is of the arch-bar or diamond



FIG. 3—INTERIOR OF LOW FLOOR CAR
Showing seating arrangement.

frame type. The general dimensions of the truck are given in Table II. The upper side member consists of a three inch channel (5 lbs. per foot) and the bottom member is a 3 by 3/8 inch bar.

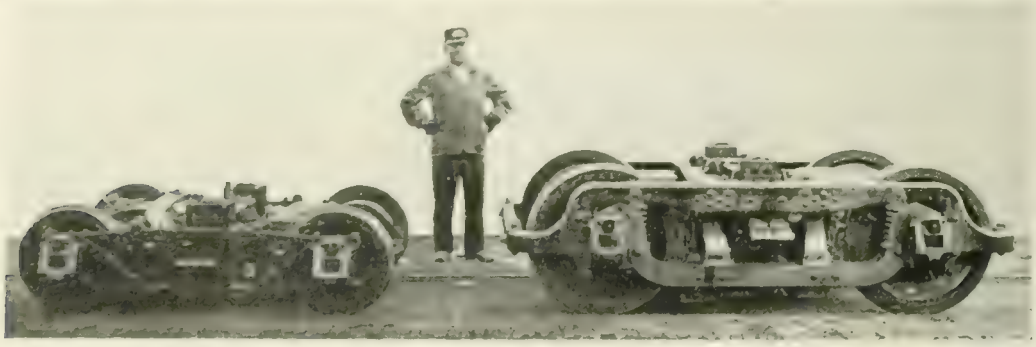


FIG. 4—VIEW OF STANDARD AND SPECIAL TRUCKS
Showing comparative sizes of trucks provided with 24-inch and 34-inch wheels.

The transoms are six inch channels (10.5 lbs. per foot) and the truck bolster is of the truss type made up of a seven inch channel (14.75 lbs. per foot) and a 5 3/4 by 3/4 inch bar. The journal boxes are made for 3 1/4 by 7 inch journals and are rigidly bolted to the

side members without springs. The trucks are designed for a normal center pin load of 17 500 lbs., with a factor of safety of 7.

LAY-OUT OF APPARATUS

As might be imagined on a low floor, light weight car of this description one of the difficulties was to find suitable locations for the electrical and air brake apparatus. There is no doubt that a considerable saving in weight can be secured on many cars of

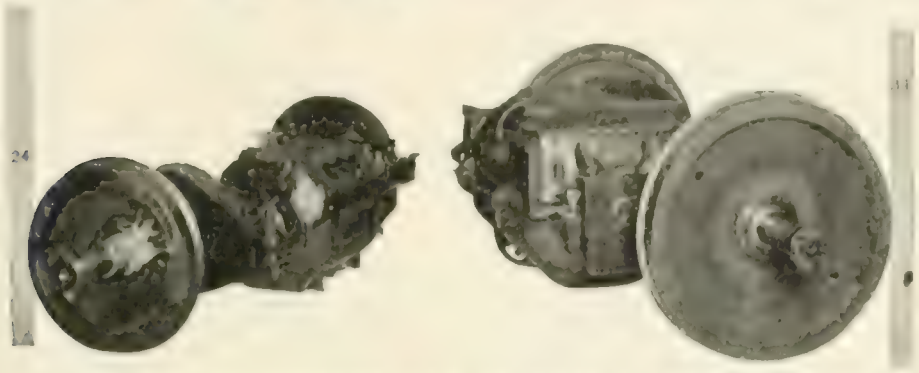


FIG. 5—COMPARATIVE VIEW OF WHEELS AND MOTORS

ordinary design by a more economical design of the various hangers, as well as by a more suitable arrangement of the underframing to accommodate apparatus without the use of hangers. The power circuits under the car are carried in iron conduits. These conduits, as well as the air brake piping, are carried between the center sills through openings provided in the cross sill members. The motor and resistance wires are made up in standard four conductor cables, with a separate conduit for each cable. This provides an inde-



FIG. 6—COMPARATIVE VIEW (DIAMETERS) OF REGULAR AND SPECIAL ARMATURE

pendent circuit to each motor and two circuits for the grid resistance. The control wires for the contactor are also carried in conduit.

MOTORS

Probably the most interesting and most important element of this equipment is the "baby" motor. It was laid out along the following lines:—

The most radical change from the standard consists in the

elongation of the motor dimensions along the axis of the armature; the introduction of a fan blower on the pinion end of the armature;

TABLE III—COMPARISON OF CHARACTERISTICS OF SPECIAL AND STANDARD MOTORS

Motor	Special	Standard
Type number	W—328	W—306
Horse-power	30	50
Speed at full load, r.p.m.	585	578
Weight of motor only, lbs.	1480	2400
Weight, per horse-power	49.3	48
Weight of armature, lbs.	377	608
Ratio diameter to length	77	147.5
Wheel diameter, inches	24	34
Height of top of frame above rail, inches	28¼	30¼
Gear ratio	3.56	4.60
Gear and wheel reduction	5.02	4.60

the use of heat proof insulation in armature and fields. The design and operating characteristics of the motor can probably be best appreciated by a comparison with the standard motor which it replaces, as given in Table III.

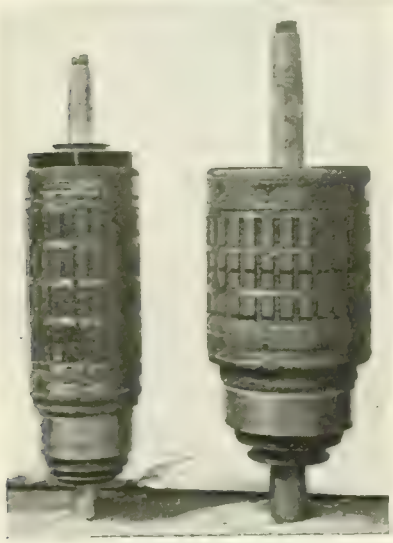


FIG. 7—COMPARATIVE VIEW (LENGTH) OF REGULAR AND SPECIAL ARMATURES

The most striking feature of this design is the ratio of diameter to length, which is practically one-half on the smaller motor as compared with the standard. The full-load speed and the weight per horse-power are practically identical.

Some of the operating characteristics, including data on the cars are given in Table IV.

The saving in rheostatic loss for each accelerating period is the difference between 2.82 watthours per ton and 2.04 watthours per ton, or about 27.5 per-cent. The saving in power expended in developing the stored energy of the rotating armatures and wheels is the difference between 10.4 watthours and 3.8 watthours or 6.6 watthours for each period of acceleration. The same result is obtained by comparing the actual foot pounds of stored energy. This is 23 800 foot-pounds in case of the standard and 8 260 foot-pounds in case of the special motor, and the difference of 15 520 foot pounds is equal to 2.35 horse-power if developed in 12 seconds.

The characteristic curves of these two motors are shown in Figs. 8 and 9, where the comparison is made between the same percent-

TABLE IV—OPERATING CHARACTERISTICS OF SPECIAL AND STANDARD CARS AND MOTORS

	Special Motor	Standard Motor
Car weight equipped, lbs.	37 500	47 600
Car weight loaded, lbs.	43 000	57 100
Number of passengers	68	68
Accelerating rate—miles per hr. per sec.	1.5	1.5
Total tractive effort, per ton, lbs.	170	170
Amperes per motor for acceleration	52.7	77.0
Time in seconds accelerating on rheostats	7.9	8.95
Rheostatic loss in watt-hours per car per acceleration	43.9	80.5
Same in watt-hours per ton for each acceleration	2.04	2.82
Torque for armature stored energy at 1.5 miles per hr. per sec.	9.54	28.2
Torque for armature and wheel stored energy	15.8	42.3
Amperes per pound torque	0.153	0.147
Amperes for armature and wheel stored energy	2.3	6.2
Watthours for stored energy of rotation for each acceleration.	3.8	10.4
Actual stored energy of rotation at 18 miles per hr. in foot lbs.	8 280	23 800

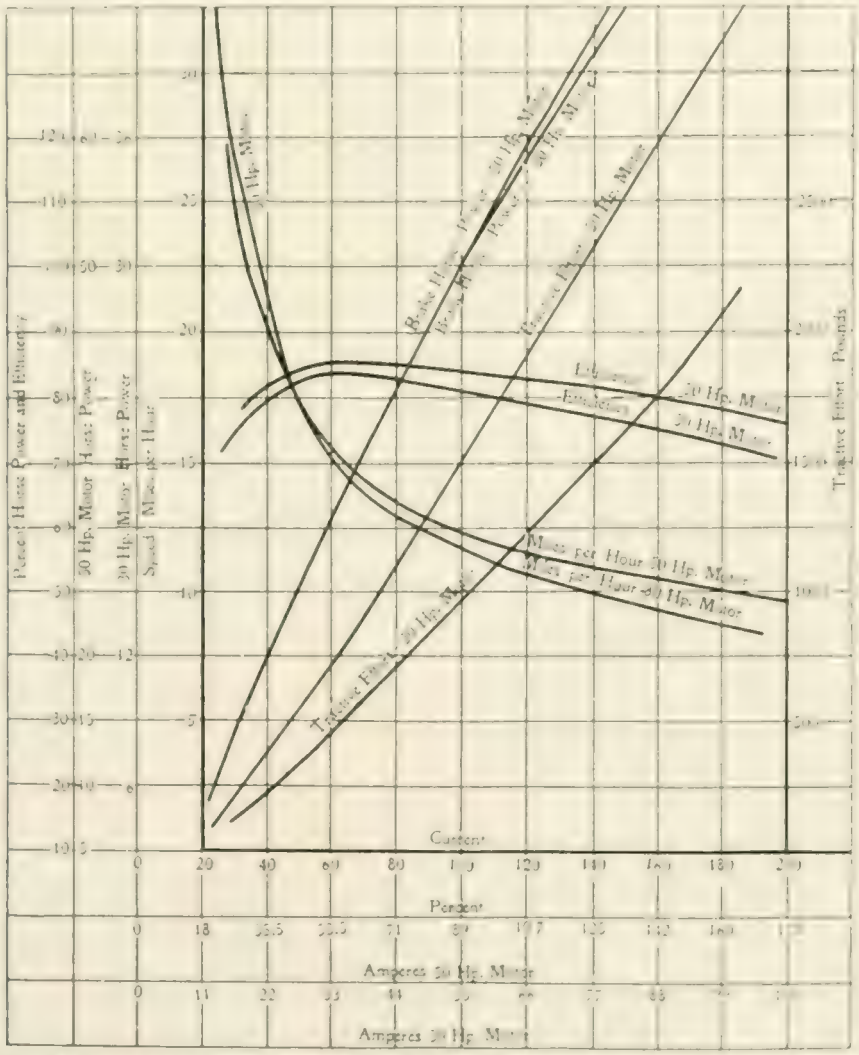


FIG. 8—CHARACTERISTIC CURVES OF 30 AND OF 50 HORSE-POWER MOTOR

age of full load current in each case.

A more correct comparison between the load and speed is

shown in the "Speed-Torque" curves. In this case the tractive effort developed by each motor is based on the actual weights of the cars on which they are operated. Since these weights are in the ratio of 57 100 lbs. to 43 000 lbs. the 50 horse-power motor must develop a tractive effort of 1330 lbs. when the 30 horse-power

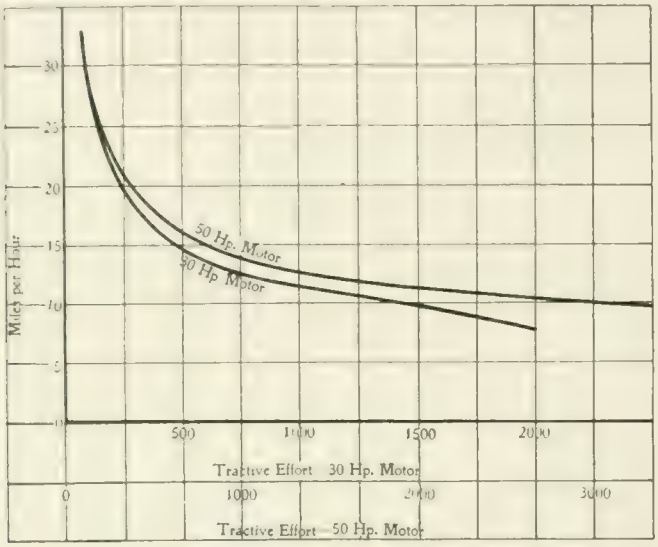


FIG. 9—COMPARISON OF SPEED-TORQUE CURVES

motor is developing 1 000 lbs. In this way the speeds of the equipments are compared on an actual operating basis.

RESULTS OF TESTS

A number of actual tests have been made on these equipments, a few of which are given in Table V. These test figures when compared with similar figures for standard cars and equipment show a considerable power saving. Aside from the other desirable features of this car, the general comment of the public, and

TABLE V—COMPARISON OF WATT-HOURS PER TON MILE

	Special Car and Motor
Frankstown (no trailer)	139
Center and Negley (trailer)	125
South Highland (trailer)	118
North Highland (no trailer)	130

of railway men and engineers who have had an opportunity to ride on it while in service, is the remarkable smoothness of operation. One prominent engineer stated that it rides as though it had rubber tires.

The car is covered by patents held by Mr. P. N. Jones, general superintendent, and other patents are pending. The development of the "baby" motor was made at the expense of the Pittsburgh Railways Company, whose officials were unable to get any manufacturer to assume the expense of bringing out such a motor.

THE NEW YORK, WESTCHESTER & BOSTON RAILWAY SYSTEM

A NEW 11 000 VOLT, SINGLE-PHASE INTERURBAN ELECTRIC RAILWAY, WITH MULTIPLE-UNIT OPERATION OF CARS

PICTURE a suburban electric railroad whose inception, design and realization have had behind them the most modern ideas and methods; a road equipped for safe high speed operation with dense traffic, and running through sections which, though developed, have been practically without immediate railroad facilities; a road without grade crossings, built through a rolling country with scarcely any part of it following the natural level, yet with no grades exceeding one percent except at one connecting point and one terminal—and one has a view of the New York, Westchester & Boston Railway System which reveals its importance and some of its possibilities.

A company bearing the present name was organized under the laws of the State of New York to build a railway from the Harlem River through what was then Westchester county, now the Bronx, thence to Port Chester, with a branch line from Mt. Vernon to White Plains, and another branch through Clason Point to Throgg's Neck. The franchise, which was granted by the Board of Aldermen of the City of New York about the middle of the year 1904, specified in its requirements that the company should construct and operate a four-track railway over a route therein specified in the Borough of the Bronx, by means of electricity or other mechanical motive power except steam, subject to certain conditions therein set forth.

Another company, the New York and Port Chester Railroad Company, was also organized under the laws of New York State, to build a railway over a route substantially the same as the New York, Westchester & Boston Railway Company, except that there was no branch line to White Plains, and the Bronx branch ended at Clason Point. In May, 1906, a franchise was granted by the City of New York, including the right to cross certain streets and highways, to construct and operate a railway by means of electricity or any other mechanical motive power which might be lawfully employed, except steam locomotive power, in the Borough of the Bronx, City, County and State of New York. The Public Service Commission on December 16, 1909, issued an order permitting and authorizing the New York, Westchester & Boston Railway Company and the New York & Port Chester Railroad to

consolidate, subject to certain conditions which were accepted by the new company, the new organization to take the name of the former company.

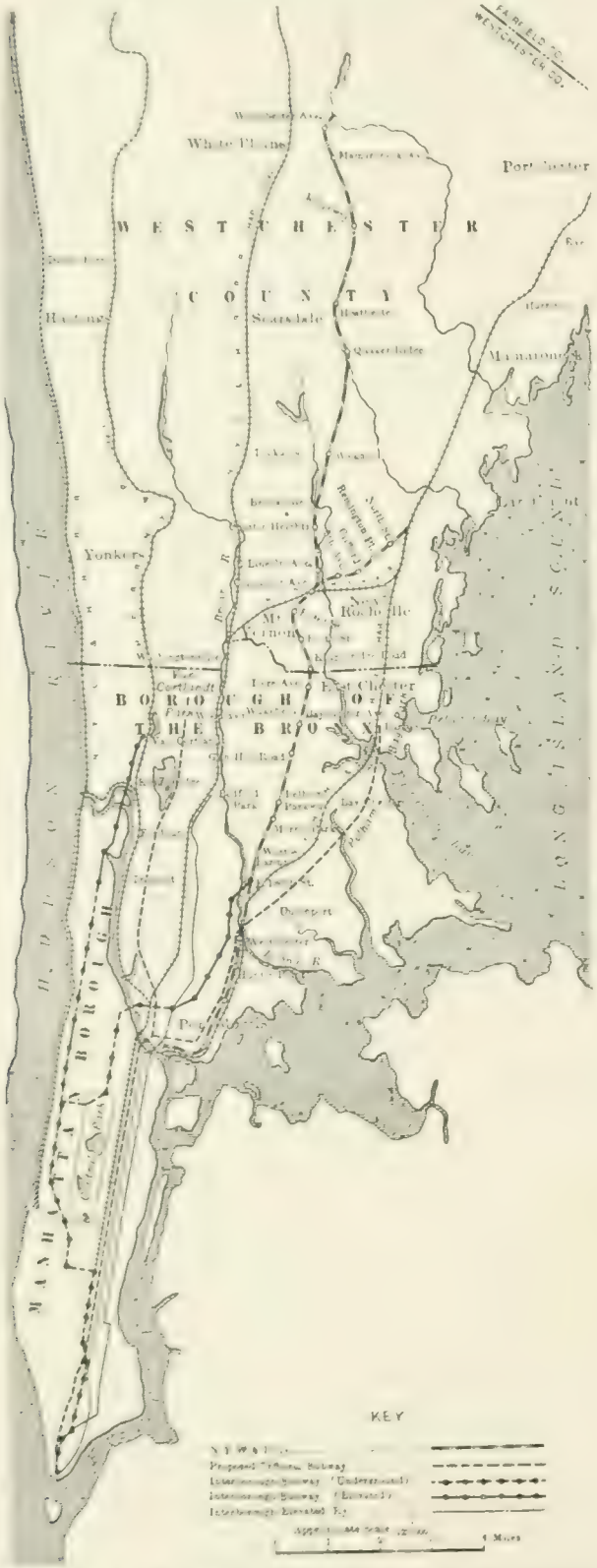


FIG. 1—MAP OF NEW YORK CITY AND SUBURBAN DISTRICT NORTH

Showing territory served by New York, Westchester and Boston Railway.

TERRITORY SERVED

An inspection of the outline map, Fig. 1, shows the territory served, which, outside of New York, comprises the cities of Mt. Vernon, and New Rochelle and the towns and villages of North Pelham, Scarsdale, East Chester and White Plains. The terminal of the New York, Westchester & Boston is at the Harlem River where connections are made with the fast express and local trains of the Second and Third Avenue elevated. From thence north the tracks of the Harlem River branch of the New York, New Haven & Hartford Railroad are used in common as well as the stations at Port Morris, Casanova, Hunts Point and Westchester Avenue. With its own right of way from this point north, the Westchester System has four tracks from New York

into Mt. Vernon and double tracks beyond on the main line and the White Plains branch. From a point near the present West Farms station on the joint tracks, the New York, Westchester & Boston Railway diverges from the Harlem River branch of the New Haven road, and makes its first independent stop in the transfer station at 180th Street near the eastern border of Bronx Park. Here connection will be made with the West Farms branch of the Interborough Subway, and in that vicinity with the tracks of the Triboro route, when built, allowing quick transfer for all points reached by them. From the point of connection with the four main tracks of the Harlem River branch of the New Haven system near 174th Street, New York City to Mt. Vernon, the four track section is 6.8 miles in length. At Mt. Vernon it separates into two double track lines one extending eastward approximately 2.1 miles to New Rochelle, where it connects again with the New Haven system, and the other continuing northward for 9.4 miles to White Plains. From Mt. Vernon to White Plains the line is almost parallel with the New York Central, and is separated from it about 1.5 miles. The junction point of the White Plains branch and the line to New Rochelle is just north of the Columbus Avenue station. The distance from the Harlem River station to the North Avenue station at New Rochelle is 12.23 miles. In general the rapid transit routes in Westchester county run north and south and are controlled by the New Haven and New York Central Railroads. Cross country connections are afforded by electric street railroads, so that this territory is now admirably provided with transportation facilities.

SERVICE AND SCHEDULES

One of the primary ideas in this project was that adequate facilities should be furnished for the transportation of passengers in the territory served by the Westchester System. While the minimum number of trains that may be operated, and the hours of service, have been regulated by law, the initial service inaugurated by the company is far in excess of the minimum requirements stipulated in the franchise.

Stations on the four track and New Rochelle sections are at intervals of approximately one-half mile, while on the White Plains branch stations are about one mile apart. The express stations, of which there are seven, are approximately two and one-half miles apart. The average speed of trains including stops is 37 miles per hour for express trains, allowing 25 seconds for each

stop, and approximately 22 miles per hour for local trains, allowing 15 seconds for each stop.

The equipment of the road and the construction of the right of way throughout provides for the heaviest kind of suburban traffic with multiple-unit cars. A normal maximum running speed of 57 miles per hour is provided for. To handle such traffic with safety and without delays, the system is provided with highly perfected block signaling and, in addition, a complete equipment for telephone communication between stations and between the interlocking towers at switching points.

An inspection of the schedule of trains shows a total of nearly 60 north-bound and 60 south-bound locals and about 50 north-bound and 50 south-bound express trains on the four track section between the Harlem River station, New York City, and the East Third Street station, Mt. Vernon. Thus, in the main, the locals and express trains are operated alternately throughout the day. There is little diminution in the service on Sundays. From 1:00 A. M. to 4:00 A. M. trains will not be required to be operated for the first five years. Between Mt. Vernon and New Rochelle and between Mt. Vernon and White Plains all trains, whether express or local, make all stops. A striking feature of the schedule of trains is that throughout the day, north-bound locals and expresses are due to arrive and south-bound locals and expresses to leave the East Third Street station, Mt. Vernon at the same time, passengers being permitted to change from local to express trains and vice versa at this point. The express service between Mt. Vernon and New York City is, for example, 16 minutes as against 28 minutes for local service according to the running time of one period of the day, while at another period the express service is about 17 minutes as against 27 minutes for local service, the distance between the Harlem River station and East Third Street, Mt. Vernon, being scheduled as 9.85 miles.

In general, a south-bound express from White Plains is followed by an express from New Rochelle, and a local from White Plains by a local from New Rochelle. The average time between locals and likewise the average time between express trains is 20 minutes. In other words, the schedule is so arranged that a local train from White Plains going south reaches the East Third Street station, Mount Vernon, at the same time as an express train from New Rochelle, and vice versa. Thus, each branch service supplements that of the other and gives a ten minute express service to New York, with the alternate expresses on a twenty minute

headway, and the local service on a twenty minute headway. The corresponding schedule for north-bound trains provides for an express train to New Rochelle every forty minutes and a corresponding train to White Plains at East Third Street station every forty minutes. Likewise there is a local train alternately to New Rochelle and White Plains every forty minutes. The schedules are based on the plan that local trains will consist of one car each and express trains of three cars each, the cars being designed to seat 78 passengers.

The regular service will eventually be based on a fifteen minute headway for both express and local trains on each branch. This will give a headway of seven and one-half minutes both for the express and the local trains on the four track section between New York and Mount Vernon. It is planned to run on the same headway practically all day both on week days and holidays.

According to a stipulation in the franchise granted the company, the fare within the city limits of New York during the first twenty-five years of operation must not exceed five cents for one continuous ride from any point on the road to any other point thereon or branch or connection thereon. In connection with the traffic operation of the road as a whole, the system is segregated into eight five-cent fare zones, with tickets of distinctive colors for the respective zone. To cover five cent rides between stations located in two adjacent zones, two-color tickets are issued, the colors in each case being those of the adjoining zones. After purchase of a ticket at a given station, it is inspected and punched by an attendant at the turn-stile before entering the car, but it is not collected until after leaving the car at the station of destination. This method provides a novel means of avoiding the annoyance of ticket inspection en route, a system which has been successfully used abroad. The total fare between Harlem River station and White Plains is 35 cents. A system of sixty-ride commutation tickets is also in effect.

RIGHT OF WAY, STRUCTURES AND BUILDINGS

As this system follows a new route from Mt. Vernon north with a private right of way, it was possible to provide for a type of track construction which would be in line with the most modern approved methods. This is an essentially important point, in view of the high speed of operation and the heavy traffic conditions under which operation will eventually have to be maintained when the territory through which the line runs becomes fully de-

veloped. Relatively expensive types of construction have been used but with the prospect, in the long run, of minimizing the cost for up-keep.

The Company now has under operation a total of 17 miles of its own right of way. As the country traversed is very uneven, the majority of the line is made up of cuts and fills or special structures. The cuts comprise seven miles, mostly through solid rock and of an average depth of 16 feet; the fills amount to over nine miles, the average depth being 14 feet. For the fills, large rock was used. The road is rock ballasted throughout. The track is laid with 90 lb. steel rails on creosoted pine ties, tie plates being used except on tangents. There are no grades over one per-cent with the exception of the approach to the four track connection with the New Haven Road at 174th Street and the White Plains terminal. Curves do not exceed four degrees except approaching certain express stations, at which points the speed is reduced. The entire right of way is protected by a substantial iron fence. This railway represents in its roadbed, stations, equipment and motive power the highest standard of road construction known to date.

Included in the special structures which were necessary in completing the right of way is a four track subway, the construction of which was required by franchise. The owners of the property in this section had arranged to build a street over the roof of the structure. The length of this subway is 3940 feet. There are two four track steel viaducts; the longer of these is located at 180th Street and is 2100 feet in length. It crosses seven streets and forms part of the 180th Street station. The four track viaduct at the Columbus Avenue crossing over the New York, New Haven and Hartford right of way includes a bridge with 116 foot girders. The two track viaduct is near the Fifth Avenue station, Pelham, on the main line north of Mt. Vernon. In order to eliminate all grade crossings, 45 steel railway bridges and 22 highway crossings have been required. The bridges comprise 11 percent of the roadbed. Four concrete arches had to be constructed. The largest highway crossing, at North Avenue, New Rochelle, is 138 feet in length.

In the construction of the stations most pleasing results have been obtained. Many forms of construction were necessary because of the difference in level of the track relative to the natural ground level. In each case the entrance to the station is on the street level, the station building being under or over the track, as

may be required, at railway and street bridges. A number of stations have electric elevators to facilitate traffic between the platforms and the street. Three distinct types of architecture were followed according to environments. The opinion has been expressed that the passenger stations and signal towers constitute the most attractive group of way structures to be found on any electric or steam road in this country. It is evident that the company wished to erect buildings which would combine beauty and utility and add to, rather than detract from, the developments of the surrounding sections.

The stations and platforms are of fire proof concrete construction as it was determined upon careful investigation that structures of this design would be much more permanent and could be maintained at less expense than any other possible types. With a further view to the expected development of the territory the stations have in many cases been made of larger size than actually required in order to allow for additional space for rental purposes. Thus many of the stations have cafes and various other stores in addition to the usual news and confectionery stands. In some cases the local real estate agencies make their headquarters here.

POWER SUPPLY

Power for the operation of the Westchester Road is supplied by the Cos Cob power station of the New York, New Haven & Hartford Railway, which is about 13 miles from the junction point of the two roads northeast of New Rochelle. Connection is made to the high voltage, 25 cycle, single-phase feeders which supply power to the main line of the New Haven Railroad. Certain of the feeder circuits follow the four track section south from the Columbus Avenue station, Mount Vernon, while others follow the two track branch to White Plains. At the Cos Cob station the power is generated three-phase and normal line voltage is maintained by means of a Tirrill regulator which controls the voltage of one phase only. The remaining phases, however, are also loaded by operating motor driven elevators, pumps, etc. Three-phase lines supply the power for these motors. For the lighting of stations, 25 cycle power is supplied from feeders, and local direct-current loads are supplied at several points by means of rotary converters.

OVERHEAD CONSTRUCTION

In the selection of the high voltage, single-phase system, the

New York, Westchester & Boston engineers had the benefit of the operating experience on the New Haven system. As a result of this experience the entire overhead construction of the present system represents the incorporation of only those features which have been successfully proven by actual service. The catenary suspension system is of much simpler form than the original New Haven designs, and a much higher factor of safety as regards continuity of operation and general freedom from line troubles has been introduced and the catenary bridges have been made much lighter and cheaper without sacrifice of necessary strength.

Compound Catenary Construction—The overhead construction

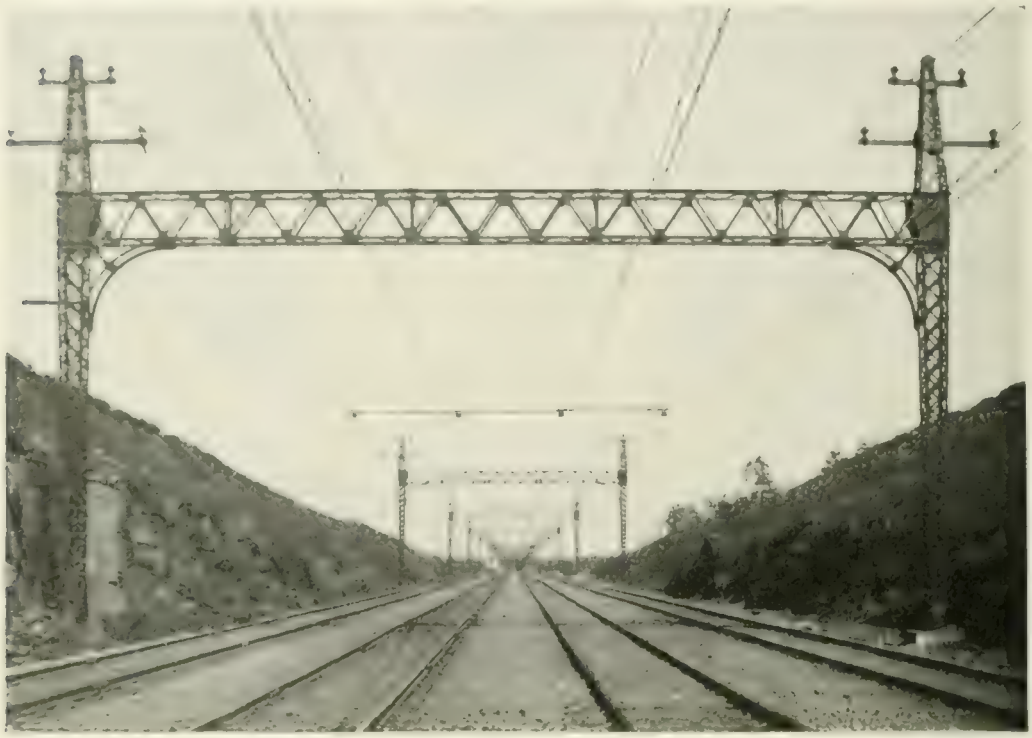


FIG. 2—COMPOUND CATENARY TYPE OF OVERHEAD CONSTRUCTION FOR SUPPLYING 11 000 VOLT, 25 CYCLE, SINGLE-PHASE POWER

is identical with that used for the new Harlem branch of the New Haven system. A form of catenary construction illustrated in Fig. 2 is the type used throughout the majority of the system. It will be noted by referring to this illustration that there are two messenger cables used for each track, one a seven-eighths inch stranded steel cable, serving as a main supporting cable carried over the top of the catenary bridges to which direct attachment is made by means of iron clamps. The main supporting cables are therefore grounded. The supporting bridges are spaced 300 feet apart on all tangents. At curves, and at certain overhead crossings the spacing is reduced, the minimum spacing at curves being 200

feet. At all curves of over four degrees, auxiliary pull-off poles are erected in order to provide for the required side strain. Intermediate between bridges these cables support two three-inch I-beams spaced 150 feet apart and attached to them by means of triangular clamps. For the four track section the I-beams are of sufficient length to span the four tracks. The catenary construction for each trolley wire is supported from these cross beams by means of double petticoat insulators, which stand a dry test of 110,000 volts, thus introducing a very high factor of safety for the line insulation, a feature which has been found to be not only expedient, but very successful as a means of reducing line troubles



FIG. 3—COMPOUND CATENARY CONSTRUCTION AT CURVE

and simplifying the problem of lightning protection. For the catenary construction proper, a five-eighths inch stranded cable is used. From this catenary cable a horizontal No. 0000 grooved copper wire is hung by means of vertical hangers of different lengths, spaced ten feet apart. One and three-quarters inches, center to center, below the copper wire is hung a No. 0000 grooved steel contact wire. The two wires are connected at ten foot intervals by means of clips so spaced that they will be midway between the hangers from the supporting cable. This type of construction combines the necessary flexibility and conductivity of the contact wire with strength of construction. At curves a special type of offset hanger is employed, a variation from the method employed

on tangent construction being that, instead of the hanger being located between clips, the hanger is attached directly to the clip. In this way the vertical alignment of the copper conductor and steel contact wire is maintained independent of side strains. The required flexibility is still obtained in view of the angular position of the hangers. The details of a typical section of overhead construction at curves are shown in Fig. 3.

Low bridges, which have previously been a problem to engineers in maintaining insulation, have been adapted to the catenary construction by being made a part thereof. Previous constructions have made it necessary to insulate the messenger cable,



FIG. 4—COMPOUND CATENARY LOW-BRIDGE CONSTRUCTION

The main supporting cable is clamped directly to the bridge beams, the secondary catenary being suspended from insulators attached to cross beams on each side of the bridge. The copper conducting wire and trolley contact wire, and the secondary catenary which supports them are thus entirely clear of the bridge.

which of course takes up needed space in the equipment of low bridges. The simplification of this problem, when the compound type of catenary construction as now installed is employed will be evident from Fig. 4. Much attention has been given to the location and maintenance of the contact wires directly over the center of the tracks.

Design of Bridges—The design of all bridges is based in general upon the assumed condition of all wires being coated with

one-half inch of ice. The wind load was then assumed to be six lbs. per square foot of projected area, including the coating of ice, or twenty lbs. with the bare wire. With a suitable factor of safety this gave a very substantial construction, especially as the two assumed conditions would hardly be apt to be present simultaneously.

Circuit Breakers—Circuit breakers are located in the feeder circuits at New Rochelle Junction, at which place connection is made to the supply circuits of the New Haven system, and also at points midway on the four track section and the White Plains branch. These circuit breakers serve to disconnect the feeder circuits at their respective points of location but do not operate directly on overloads. The control wire, which furnishes power for tripping the feeder and sectionalizing breakers in case of excessive current, extends along the main four track line and along the White Plains branch and connects with the Cos Cob station. Here the main overload relay connections are such that a certain amount of resistance is automatically connected in series with the railway feeders prior to the energization of the control wire. In this way, the maximum current due to a short-circuit is limited and a short-circuit on the line causes only the circuit breakers adjacent to the fault to open, thus localizing the trouble. The line circuit breakers are in each case located on overhead anchor bridges.

Sectionalizing circuit breakers are located at the terminals of the four track section and at the ends of the two double track sections, the sections in each case being cross-connected at the ends by a bus-wire which extends the length of the anchor bridge. By means of the line disconnecting breakers and feeder sectionalizing breakers the road is divided into sections. Thus, any section can be cut out of service in order to make repairs. No live line repair work is done, in view of the high voltage and the presence of overhead grounded wires. After a section is disconnected, and before repair work is started, the line is grounded directly to the rail by means of a wire as a further protection.

Lighting of Stations—Power for the lighting of stations is obtained by means of transformers which are installed in duplicate at each station and which reduces the voltage to 110. An emergency service is also to be provided for in the underground section north of Morris Park. Air compressors, elevators and motors for other service required along the line are operated by means of three-phase power transformed from the high-tension power supply lines.

Maintenance Car—For the use of the line maintenance department a gas-electric repair car is provided. This car is equipped with a revolving jib crane with a lifting power of ten tons to three tons, depending upon the position of the hook in the boom. There is also an elevating platform arranged with four arms so as to give parallel motion and keep the platform horizontal, independent of its elevation. This platform is operated by means of the motor driven crane hook. The boom can be swung sidewise so as to make working possible on the track adjacent to the one on which the car stands. The maximum speed of this car is approximately 30 miles per hour.

ROLLING STOCK

The initial equipment of the road consists of 28 steel passenger coach, multiple-unit cars and two steel combination passenger and baggage, multiple-unit cars arranged for operation on 11 000 volt, 25 cycle, single-phase alternating current. These cars are designed to afford unusual protection against accident, as the main shock resisting members practically enclose the entire space occupied by passengers. The construction employed leaves the under side of the car body free for the convenient arrangement of the electrical equipment.

As the station platforms throughout the Westchester system are constructed so that they will be on a level with the car floor, entrance to the cars both at the end and the middle doors is obtained without steps. However, as the cars are to be used on the New Haven Road where the station platforms are not raised, a flight of three steps is provided under the entrances, at the ends, these being covered by trap doors. The end and center side doors are operated pneumatically by means of electric control switches located in the vestibules. The coaches are approximately 70 feet in length, 9 ft. 7¾ in. wide and 13 ft. 3½ in. high, from rail to roof. Thirty-five car seats and four short longitudinal seats adjacent to the side doors give the car a seating capacity of 78 passengers. The design of the combination cars is similar except that a compartment about 16 feet in length is provided at one end for baggage, there being 4 ft. 3 in. sliding doors at each side for this compartment. In these cars the seating capacity is reduced to 54 passengers.

The car weight as equipped for electrical operation is approximately 120 000 lbs. A general view of the regular motor car

completely equipped, is shown in Fig. 5 and an interior view is shown in Fig. 6. The steel construction used for these cars requires special provision for heat insulation, a material being used which has proven successful for such purposes. Fifteen of the



FIG. 5—N. Y. W. & B. RY. 11,000 VOLT, 25 CYCLE, SINGLE-PHASE MOTOR CAR

Showing arrangement of middle and vestibule side doors. The two motors are carried on the truck at the right-hand end; the other truck is without motors. With all electrical and braking equipment installed, the appearance of the car indicates its light, open, yet substantial construction. The control is arranged for multiple operation in trains.

cars are provided with one type of ventilation system and the balance of the present equipment with a second type in order to determine the comparative effectiveness of the two systems. All



FIG. 6—INTERIOR OF N. Y. W. & B. RY. MOTOR CAR

In addition to the regular lighting system operated from a 110 volt tap on the auto-transformer, there is an auxiliary circuit of lights operated from the 32 volt storage battery in case the car is without power.

cars are provided with electric heaters located under the seats and controlled by thermostatic switches to give approximately constant temperature.

Draft Gear and Couplers—The draft gear and couplers of this car correspond to the standard equipment used on the heaviest steam railroad passenger cars. Pullman type diaphragm vestibules are used. The draft gear has a capacity of 175 000 lbs.

Trucks and Braking—The trucks used for motor truck and trailer are similar in design. For the latter, however, smaller wheels and a modified arrangement of truck rigging is used. A view of the motor truck with motors installed is shown in Fig. 7. Each motor truck is fitted with eight brake shoes, there being one on each side of each wheel. With this arrangement the pressure per brake shoe is reduced to a reasonable amount in case of emergency application of the air brakes, and heating of air brakes is minimized. This feature is most important in view of the fact that the high schedule speeds and frequent stations on this system require frequent and heavy braking. In fact, the operating re-

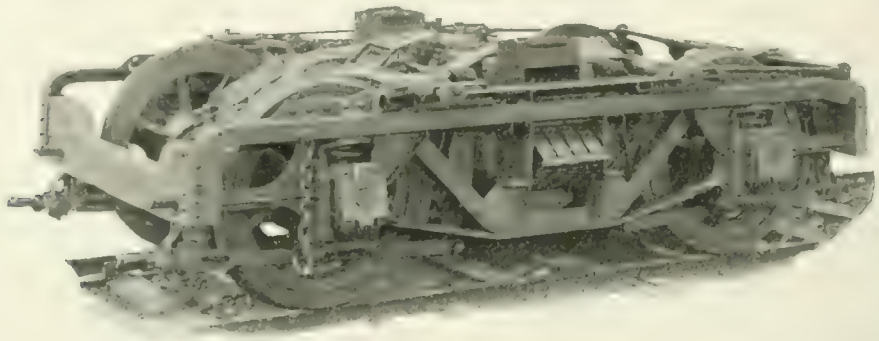


FIG. 7—MOTOR TRUCK
Showing motors and brake rigging installed.

quirements of this service have necessitated the use of brakes of higher power and greater efficiency than has been found in any other steam or electric service of the few years past. The functions of the ordinary quick acting automatic air brake have been supplemented by additional features such as the use of electric control for the pneumatic portion of the brake apparatus. Both service and emergency application of the brakes are under electric control. In case of failure of the electrical control, the pneumatic control is operative. The compressed air for braking and other purposes on the car is controlled by a governor synchronizing system which insures an equal division of load on the compressors of all cars operated in multiple. For service application the maximum pressure is limited to 50 lbs., the brake pipe pressure being 70 lbs. In case of emergency application the full main reservoir pressure of 90 to 100 lbs. is available. The usual ratchet hand brake is also provided at each end of the car.

Motor Equipment—Each motor car is equipped with two six-pole single-phase motors. The mounting of these motors differs from usual practice in that the two are mounted on one truck, thus having one motor truck and one idle truck. The motor weight is carried partly on the axle, and partly by nose suspension directly on the transom. Case hardened solid gears are used on most of the equipments, but by way of experiment four cars were equipped with case hardened flexible gears. The latter have proven eminently satisfactory in that they give to the car excellent starting conditions. In fact, so far as vibration due to the 25 cycle frequency is concerned, it would be impossible for a passenger to tell whether alternating-current or direct current motors are used. The motor is of the standard single-phase type with high-grade cast steel frame, and the usual laminated steel field punchings. The compensating winding is distributed across the pole face with each coil short-circuited upon itself, thus producing only a small voltage strain between winding and ground. This is a very desirable feature for altenating-current motors. The armature is built with spider construction and is arranged with longitudinal and radial air ducts. This secures a maximum of ventilation at the hot parts of the armature. The usual canvas hoods over the end connections have been superseded by the use of a thin covering of cement which effectively keeps out all dirt and gives a good surface for radiation. The brush-holders are located so as to give the greatest degree of accessibility possible. These holders are provided with means of radial adjustment without changing the brush position in relation to the neutral.

Both armature and axle bearings are made of high grade bronze. The armature bearings are in one piece and have a babbitt lining 1/16 in. thick. Lubrication in both types of bearings is supplied by means of long fibre wool waste which, acting by capillary attraction, lifts the oil from the well and delivers it against the journal face.

Operating under forced ventilation of eight hundred cubic feet of air per minute each motor will deliver 170 hp for one hour and 145 hp continuously with a temperature rise not exceeding 75 degrees C. on any portion of the winding. A motor driven blower supplies the forced ventilation for the motors, the air being taken in through openings in the side of the car, in order to obtain as clean air as possible.

Control System—The multiple unit switch control equipment

as applied to these cars is extremely simple. The electro-pneumatically controlled switch group is shown in detail in Fig. 8. In the three running positions of the master controller, which is located on the car platform, the motors are connected without resistance to three respective transformer taps, thus giving three different running speeds. Three accelerating steps are also provided for, cast grid starting resistance being cut into circuit to limit the starting current. The acceleration is controlled by an automatic relay. The master controller with cover removed is shown in Fig. 9. The automatic current limit switch or relay is shown in Fig. 10. If the handle of the master controller is thrown directly to the third notch, acceleration is automatically controlled by the current relay, in conjunction with the switch group. The master controller is of the "Dead Man's Handle" type; i.e., it has to be held in position for operation of the car, as otherwise it automatically releases, thus opening the motor circuit and automatically applying the air brakes.

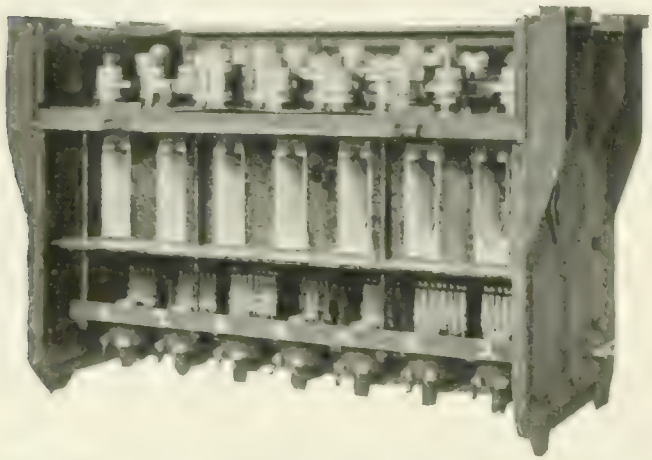


FIG. 8—ELECTRO-PNEUMATICALLY OPERATED UNIT SWITCH GROUP

Showing main circuit connections at top; blow-out compartments in the middle, and interlocking control contacts and electro-pneumatic valve magnets at the bottom.

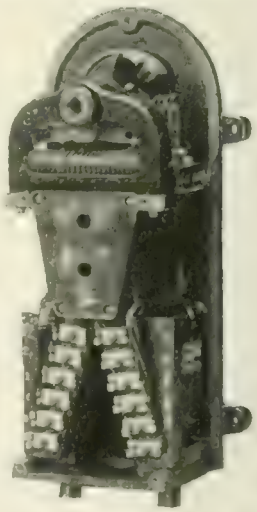


FIG. 9—MASTER CONTROLLER

View with cover removed.

An overspeed relay is included in the control equipment. It limits the speed of the cars to a maximum of 57 miles per hour. This relay is provided with a current coil connected directly in series with one of the motors and a voltage coil connected in shunt across the armature of the motor. Its operation depends upon the fact that the speed of a motor is proportional to the product of current and voltage applied; accordingly the motor may operate at a given speed with normal voltage and a given current or

with low voltage and a correspondingly increased current. The two coils of the relay act differentially upon each other.

The magnet valves of the switch group are operated from a motor-generator set in connection with a 32 volt storage battery. The motor-generator operates continuously to supply current for the control apparatus, for the operation of the electric brakes, the valve magnets of the pneumatic door operating devices, and the ten emergency lamps in the car. The battery in reality serves only as an auxiliary to the motor-generator when power is off the car.

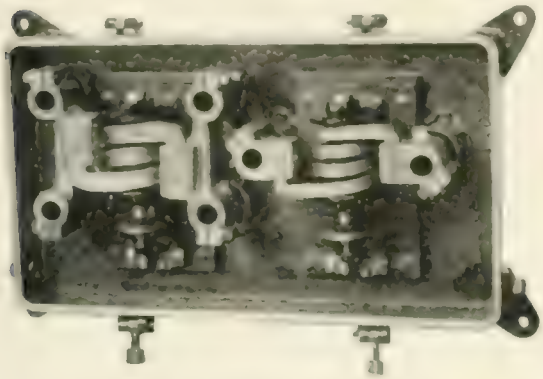


FIG. 10—CURRENT LIMIT RELAY
Showing main current and auxiliary control connections.

A high-tension oil line switch is provided for disconnecting the primary winding of the transformer from the line. A reversing switch controls the direction of operation of the car. A line relay is used in connection with the control circuits so that in case power fails on the line the unit switches of the switch group are automatically opened. When power is restored the switches will automatically close in the normal manner, provided the master controller handle has not been released. Either motor can be disconnected from the car circuits in case of trouble. The air-cooled auto-transformer is operated with forced ventilation from the blower which also supplies air for cooling the motors. The transformer is shown in Fig. 11. The total weight of motors, transformers, pantograph trolleys, switch group, blower outfit and other electrical equipment including cables, is approximately 24 500 lbs.



FIG. 11—AUTO-TRANSFORMER
Showing arrangement for forced ventilation. The 11 000 volt terminal is brought out through the sheet iron protecting case at one end by means of a porcelain bushing and extra insulated cable. The exterior of the iron is exposed to give direct radiation.

INCANDESCENT LAMPS FOR RAILWAY USE

GEORGE P. SCHOLL

NEVER in the history of train lighting with incandescent lamps have railway engineers and officials paid so much attention to the proper illumination of their cars and to the proper choice of lamps for this purpose, as they have within the last few years, and especially since the advent of the tungsten lamp. One of the first fruits of this interest was the active and friendly coöperation which they extended to the sales representatives and engineers of the lamp manufacturing companies. Every facility was afforded to the lamp companies' engineers for the experimental installation of the new types of lamps in railway cars, and careful and accurate records of their performance were kept.

The results of this active coöperation were far reaching. On the one hand, it familiarized the railway engineers to a much greater extent than ever before with the various types of lamps, and the purposes to which they could be applied; and on the other hand, it gave the lamp engineers an intimate acquaintance with the peculiar needs of the railway business. It was realized that the conditions of the railway service are such that they cause a severe strain on the lamp filaments, as far as the latter's resistance to shocks, etc., is concerned. This is especially true in the case of tungsten lamps. The lamp engineers, therefore, bent every effort to increase the ruggedness of the tungsten filament, and they have succeeded to such a degree that the tungsten filament, as manufactured at present, is practically unbreakable under normal service. Moreover, the construction of the devices which support the filament in the lamp has been constantly improved so as to adequately support the filament, and yet have sufficient flexibility to take up any extraordinary shock and protect the filament from breaking.

Owing to these improvements in construction, not only has the mechanical strength of the lamp been increased to an extent which would have seemed impossible a few years ago, but the life of the lamp has also been consistently lengthened. The average performance and the mechanical strength of all types of railway lamps are to-day better than they ever were before. Some of the largest city and suburban roads have adopted tungsten lamps for all classes of service and have obtained very satisfactory results.

It is also of interest to call attention to the satisfactory service which has been obtained by large street railways in the use of

metallized filament lamps. The reason why these roads have not gone over to the tungsten lamp is probably the initial high price of the tungsten lamp combined with the fear of the theft of such lamps. The experience, however, of the roads which have adopted tungsten lamps, does not bear out this contention and the saving in current obtained by the use of the tungsten lamps has more than offset the initial cost.

As further evidence of the strength of the tungsten lamp may be mentioned the adoption of tungsten lamps, especially the two candle-power, twelve to eighteen volt lamp for signal work. Several roads are experimenting with these lamps, and according to present advices, the service given by them is satisfactory. As this is a class of service where the mechanical breakage of the lamps formerly constituted the greatest drawback, their adoption for this use illustrates better than anything else the improvements which have been made in the ruggedness of the tungsten lamp.

Among the improvements in special types of lamps for railway use is the development of the headlight lamp for both steam and street railway use. The filament of these lamps is arranged as a so-called "point source," that is, it is arranged with the smallest possible radius in a cylindrical spiral. It is adequately supported by anchors in order to make it as flexible as possible and thus guard against damage by unusually heavy shocks or jars. Several types of these headlight lamps have been developed.

It may also be of interest to mention the improvements which have been made in the tungsten lamps which are used for illuminating large areas, such as railroad yards, sheds, etc. These lamps are from year to year, in increasing numbers, replacing arc lamps; and their ease of installation and maintenance, and saving of current gives them a very decided advantage over the arc lamp.

There will undoubtedly be a demand in the near future for lamps of higher candle-power than the five hundred watt lamps, to replace arc lamps. There is also a demand for large watt lamps in the round bulb, on account of their artistic appearance and their similarity to the shape of the arc lamp, which they are mainly intended to replace.

As far as the regular train lighting lamps are concerned, it may be of interest to mention that the wattage consumption of these lamps has been decreased from 1.23 to 1.17, thus retaining the candle-power, decreasing the load on the battery and furnishing a greater operating radius than before.

A NEW TYPE OF SPRING DRIVE FOR ELECTRIC LOCOMOTIVES

AS APPLIED TO THE LATEST NEW HAVEN ALTERNATING-CURRENT LOCOMOTIVES

J. E. WEBSTER

THE most novel mechanical feature of the new alternating-current locomotives for the New York, New Haven & Hartford Railroad is the method of transmitting the power from the motors to the driving wheels. The following are some of the characteristics of the drive as worked out in these locomotives, one of which is shown complete in Fig. 1:—

a—The motors are mounted directly on the locomotive frame and are entirely spring supported.

b—The power is transmitted to the drivers from the twin motors, Fig. 2, to one gear mounted on a hollow quill which



FIG. 1—NEW HAVEN 110-TON, 25-CYCLE, 11 000-VOLT SINGLE-PHASE LOCOMOTIVE

surrounds the axle, Fig. 3, and is carried in bearings attached to the motor frame. From the ends of the quill to the drivers the power is transmitted directly to the wheel by means of six driving springs in each wheel.

c—Each end of each spring is gripped in a holding casting. One set of these castings is bolted to the flanged end of the quill on the side of the gear and the other set is bolted to the wheels. There are no wearing surfaces in any of the spring attachments.

d—The power is transmitted to the driving axles without departure from a rotating motion. There are no reversing

thrusts to require frequent keying up or adjustment of the bearings.

e—The axles are individually driven, which means a locomotive with low friction qualities.

f—All the driving springs do duty in either direction of movement. At a given instant one-half of the driving springs are working in compression and one-half in extension.

g—Over 95 percent of the vibration due to the pulsating torque of the single-phase motors is absorbed in the driving springs. This is especially noticeable in starting heavy trains.

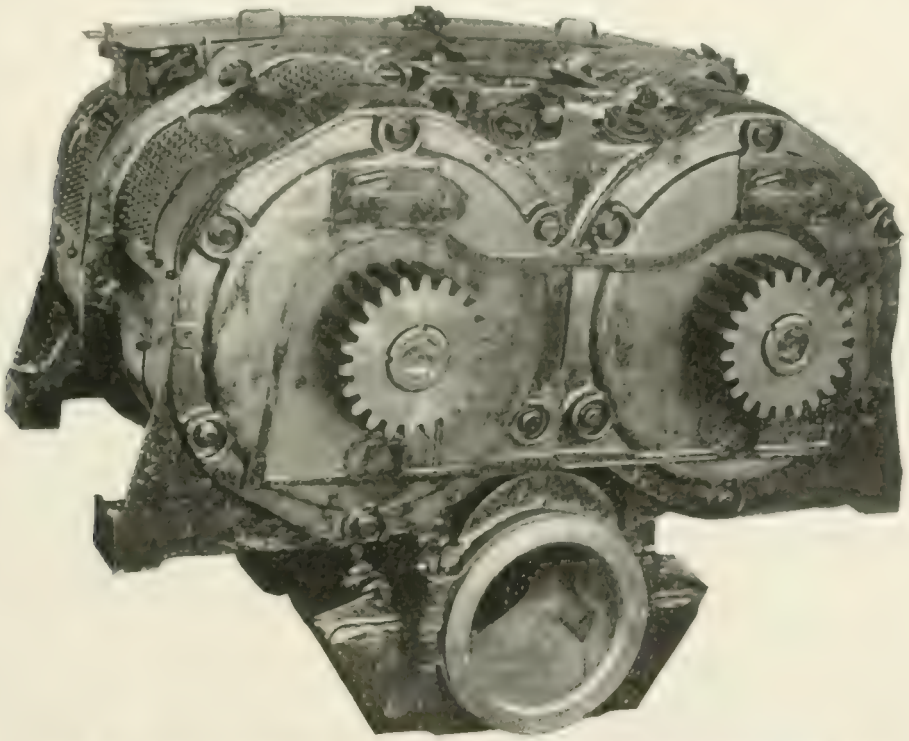


FIG. 2—TWIN MOTORS, SHOWING ONE OF THE BEARINGS FOR THE QUILL

Showing two pinions which mesh with a single gear on the quill. The four feet on the motor frames are bolted to cross bars, carried on brackets attached to the locomotive frame bolsters.

h—The driving springs are of such a number and are so mounted that it is practically impossible for a failure of any part of the drive to disable the locomotive sufficiently to cause a service delay.

i—This type of drive adapts itself especially to the use of a large number of small motors rather than a small number of large motors. In single-phase locomotives this tends to a reduction in weight and cost. The greater number of small motors

will tend to a reduction of the repair expense, as damage to an armature coil or a commutator bar will require the handling and rebanding of a small armature rather than a large one. A locomotive of a given capacity will have practically the same number of field coils, or armature coils and commutator bars no matter how many motors are used.

The illustrations show very clearly the details of construction and how the power is transmitted from two motors to the one gear and the quill which is carried in the bearings attached

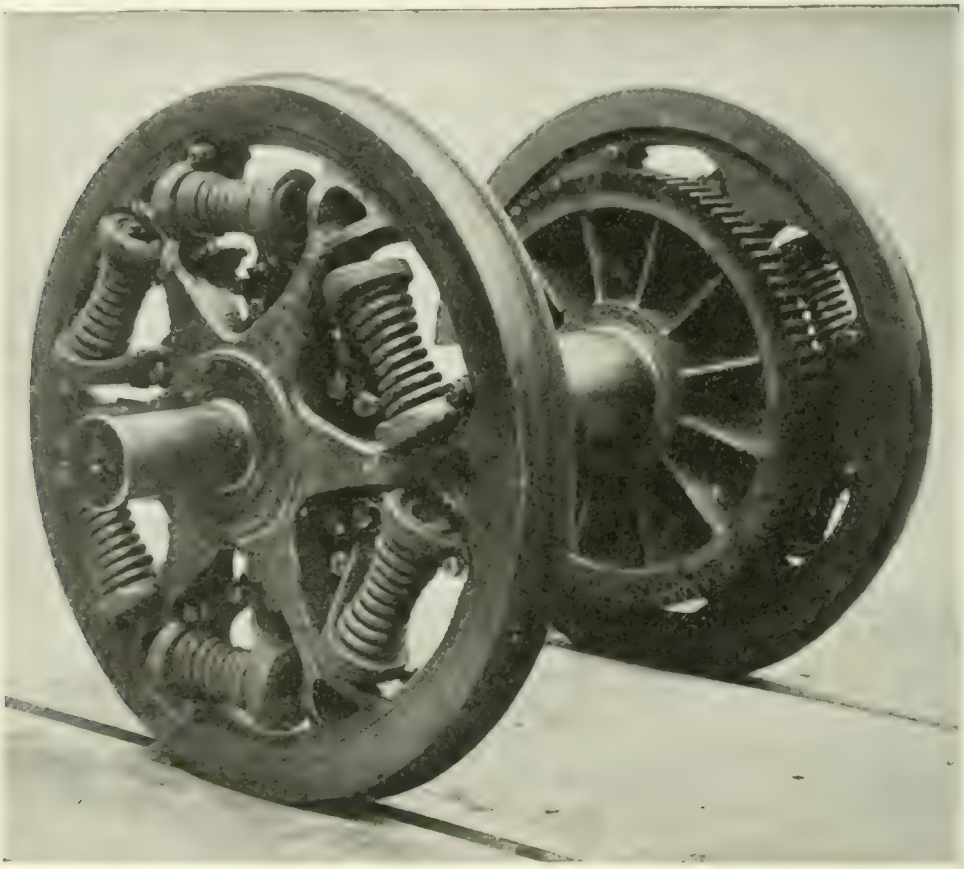


FIG. 3—VIEW OF WHEELS SHOWING SPRING DRIVE

Showing quill and gear in place. Note compact arrangement of hour glass springs in plane of wheel giving maximum spacing between wheels for motor.

to the motor frames. The details of the spring attachments are shown in Figs. 4 and 5. The spring is expanded into the spiral groove in the outer casting by driving first temporary and then the permanent wedges into the inside or spreader casting. A heavy sledge is used in driving the wedges and the expanding force is so great that the diameter of the outer steel casting is increased approximately 1/32 of an inch. A standard permanent wedge is used, the variations in the spread of the inner castings

being taken care of by spacers of various sizes. This makes it possible to obtain the maximum tightness with a short wedge



FIG. 4.—ASSEMBLY AND DETAIL VIEW OF HOUR GLASS SPRING DRIVE UNIT

which is thin enough at the point to allow clinching without interfering with the working of the spring.

The success of the drive depends on so proportioning the springs that they have ample capacity to carry the torque developed by the motor, and at the same time are flexible enough



FIG. 5.—PHANTOM VIEW OF HOUR GLASS SPRING, ASSEMBLED IN INNER AND OUTER GROOVED CASTINGS

The inner casting is split by means of a wedge after being inserted in the spring, which is locked between the two castings by means of a permanent wedge used in conjunction with a spacer of suitable size. The spacer has an offset at each end and the wedge is clinched so that both are held in place. The method of gripping the two ends is identical.

to allow the wheels to jump or follow the irregularities of the track without causing undue stresses. The useful work or

torque imposed on the spring is taken as compression or elongation as an ordinary helical spring and it is, therefore, done very efficiently.

The work imposed on any drive spring by the vertical movement of the wheels in reference to the motors depends on the position of the spring in the wheel. The springs with their axis momentarily horizontal are offset; those with their axis momentarily vertical are compressed or elongated; and those in intermediate position by a combination of offset and end compression or extension. The characteristics of the spring used on this locomotive for end deflection and side deflection are shown

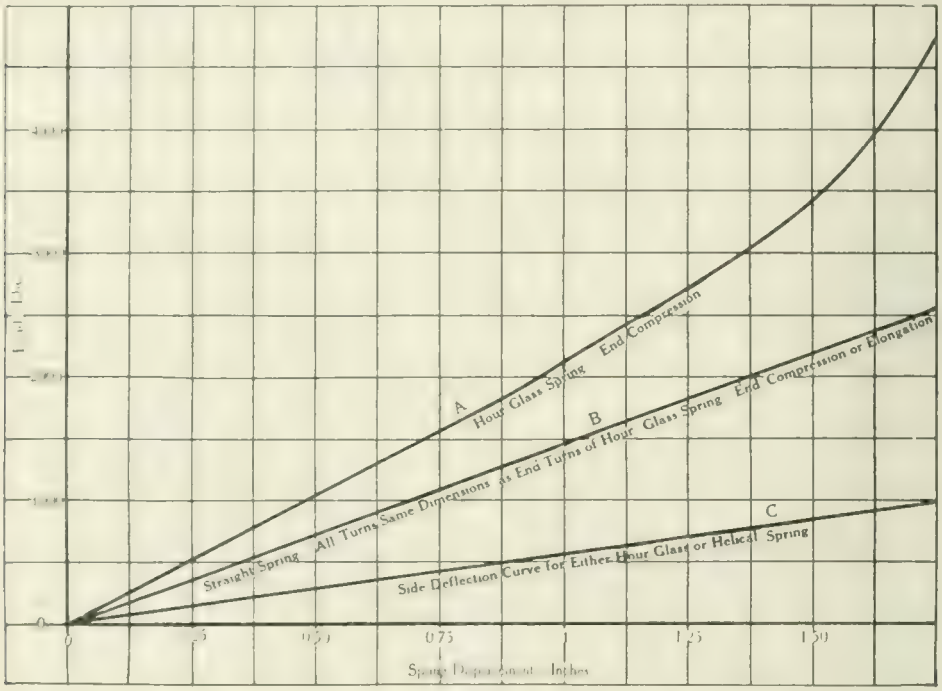


FIG. 6—CHARACTERISTICS OF HOUR GLASS SPRINGS

in Fig. 6. It will be noted that the load for a given end deflection is approximately four times as much as for the same side deflection. The maximum stresses for a given deflection are approximately the same whether the deflection is endwise or sidewise.

The stresses due to offset are a maximum in the coils adjacent to the grips and are practically negligible in the turns near the center, and the maximum stress in the end turns is inversely proportional to the diameter of the turn. In order, therefore, to keep the side stress low and to get a spring which will carry a heavy torque load, the end turns were made of a larger diameter than the center turns. Before bumping can occur, not only the end turns, but the stiff center turns must close.

Test machines were built to determine the life of springs of different proportions when subjected to repeated side deflections of different amplitude. It was difficult to determine the extent and frequency of the side deflections which the springs would have to stand. As a result, in the first locomotive equipped with this type of drive, capacity was sacrificed for side flexibility; consequently while there was no breakage of springs, there was some bumping in starting heavy trains. In order to correct this the size of wire in the springs was increased from $\frac{1}{16}$ to 1 inch and later the "hour glass" type adopted. These changes have practically eliminated the bumping, even when the wheels are slipped in starting heavy trains.

The projections or horns from the cast steel spring spreaders are set at their ends very accurately with reference to the turns

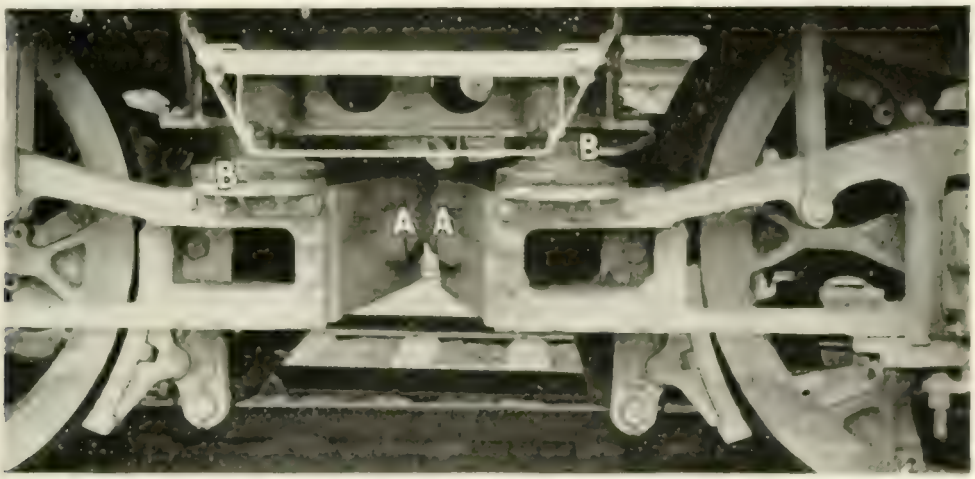


FIG. 7—DETAILS OF TRUCK ARTICULATION

The trucks are connected together by a rigid link. The spring pads *AA* take up the slack and reduce the bumping strains. With the arrangement of sliding pads, supporting spring pockets and plungers shown at *BB*, the cab floats on the two trucks regardless of lateral motion due to curves, or transverse motion due to track irregularities. The cab is held in alignment by two center pin bearings, one of which is mounted so as to provide for limited longitudinal motion, thus allowing for movement between the articulated trucks. The pin bearings, however, do not carry the cab weight.

of the spring so that: a—They will prevent large deflections of the springs due to centrifugal force. b—They will prevent a combination of side deflection and centrifugal force from stressing the spring abnormally at one end and c—They prevent a broken spring from flying out of place.

A broken spring with its holding castings can be replaced in the railroad yards by stopping the locomotive so that the broken

spring is at the bottom of the wheel. There are but five nuts to remove. New springs can be assembled in the castings in the shop. No trouble has been experienced with either armature or quill bearings. The small motors which are used with this drive allow the use of the standard railway motor armature bearings, which have been extremely satisfactory in interurban service.

The N. Y., N. H. & H. R. R. have the following locomotives in service with the helical spring drive:

8 Freight Locomotives similar to No. 084—Miles run 131 293
16 Switcher Locomotives Miles run..... ..... 39 631

There are also 33 freight locomotives of the same design as the No. 84 in process of building.

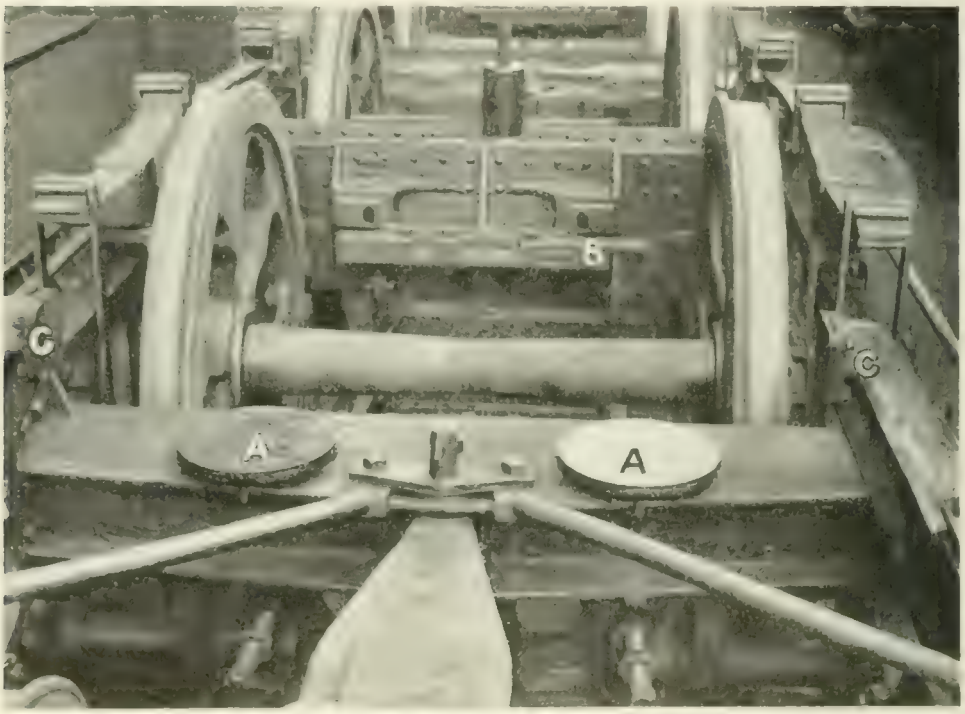


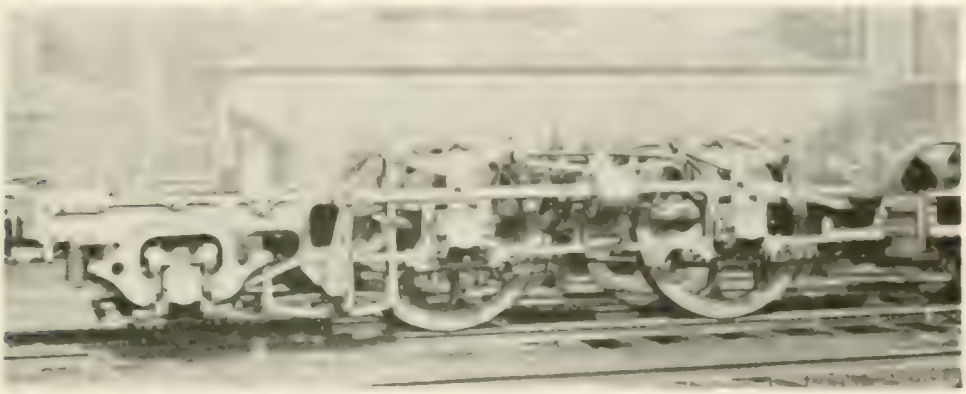
FIG. 8—TOP VIEW OF LOCOMOTIVE RUNNING GEAR

Two of the eight pads on which the cab rides are shown at *AA*. The motors are supported on cross bars resting on brackets on the bolsters as at *B*. For making repairs, these cross bars can be removed and the wheels and motors lowered into a pit. Spring plungers are arranged on the cab to engage the side bearings *CC*.

To date there have been but two drive failures, one due to the bolts holding the clamping arm coming loose and one due to breakage of a spring. Locomotive No. 069 has completed 41 264 miles with the one failure due to loose bolts. Locomotive No. 073 has completed 34 780 miles, with no failures. Of the switcher locomotives one has completed 13 096, one 8 318, and one 9 076 miles with no failures to date. While the switcher speeds are low, this mileage is all made over yard track with numerous

switches and frogs, which cause a large amount of eccentric movement of the axles in the quills.

Only standard spring steel has been used for the drive springs and no special precaution has been taken in treatment. In order to prevent excessive side deflection of the drive springs the eccentricity of the quills with reference to the axles is carefully adjusted when the locomotive is first put in service and it is checked at intervals afterwards. It has been found that there is



Showing equalization and brake rigging

but little tendency for the quills to get out of adjustment. Corrections for journal brass wear and set in the springs can be made by changing liners under the motor feet.

The performance of this type of drive is extremely satisfactory, and there are enough locomotives in service or building to conclusively prove whether or not it will have a permanent place in locomotive design.

RECENT DEVELOPMENTS IN MOTOR-DRIVEN AIR COMPRESSORS FOR ELECTRIC RAILWAYS

P. L. CRITTENDEN

THE necessity for power brakes on electrically propelled vehicles naturally led to the use of compressed air for this purpose, the apparatus used differing in principle from that already in general use on steam roads, *mainly* in the form of power used in compressing the air. The demands on the compressor have, however, steadily increased due to the addition of other air using devices outside of the brake, the use of higher pressures, more frequent stops from higher speeds and the demand for more air per pound of equipment carried.

The rapid development in electric railway equipment during the past five years has required new and improved construction in motor-driven compressors, cars and locomotives. Beginning at the latest and going backward, those developments which have most radically affected electric air compressor design have been:—

1—Extremely low and extremely light car construction wherein every effort has been put forward to reduce the weight of the equipped car to a minimum and to increase the ease of entrance to the car.

2—A demand for larger capacity compressors, without increase in weight, which would have such liberal proportions that the life of the compresors would be materially increased and repairs reduced to a minimum. This involves the best construction regardless of cost.

3—Heavy duty compound compressors for high pressure locomotive work in which the voltage is from 650 to 750 volts.

4—Heavy duty single stage compressors for moderate pressure locomotive work in which the service is so severe as to require heat proof insulation in the motor.

5—The use of line voltages of 1200 and 1500 volts direct-current.

COMBINED TYPE OF COMPRESSOR

The latest design of compact, light weight compressor known as the "Combined" type has a number of unique features. The cylinders, crank case, gear case and motor brackets are cast integral as shown in Fig. 1. This construction eliminates a bed-plate

or any tie bolts, which would be required if the motor and compressor were separate, and gives a very low construction especially adapted to the low lightweight cars now being introduced for city service. The overall height of this compressor is only 17 $\frac{9}{16}$ inches. The advantages of such a construction are obvious. Cylinders, one crank shaft bearing, and one armature bearing can be bored at one setting, besides the necessary facing of the cylinders, crank case, and gear case. This means that maximum accuracy and consequent perfect alignment are obtained when the compressor is first assembled, and that an operator has every assurance that the machine may be properly aligned if it is dismantled in his shops. This "en-bloc" construction eliminates a number of ma-

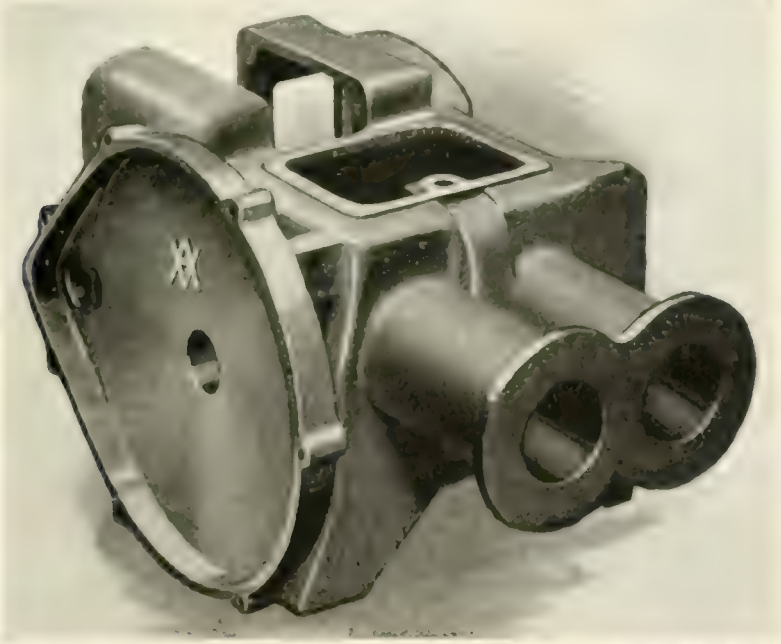


FIG. 1.—"EN BLOC" CASTING OF CYLINDERS, CRANK CASE, GEAR CASE AND MOTOR BRACKETS

chined surfaces and a large number of drilled and tapped holes.

The motor, though of increased capacity is very light. The yoke is made up of thin punched laminations instead of a steel casting. Motor yoke, pole pieces, and armature core are all punched from the same blank. Besides giving a very light and strong construction, as shown in Fig. 2, the sections can be depended upon to be uniform so that the efficiency and commutation are very good, and the heating reduced to a minimum. The commutator and armature bearing housing and the corresponding bearing for the crank shaft are bolted to the main casting. Two of the four bolts used to secure the motor bearing housing also secure the brush holder stud clamp so that after the housing has been removed

there are only two cap screws to loosen in order to swing the brush holders out of the way through the door.

The compressor proper has been designed with a view of maximum service consistent with light weight. The pistons are very long to insure even wear. The size of wrist pins and wrist-pin bearings has been increased as compared with the older construction, the connecting rod being clamped to the wrist-pin, so

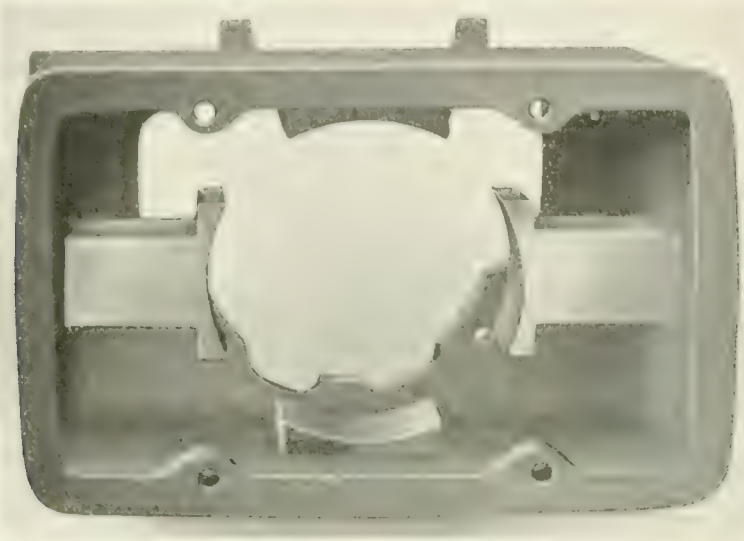


FIG. 2—MOTOR YOKE AND POLE PIECES

that the bearing is between the wrist pin and piston, and not between the wrist pin and the connecting rod. The crank shaft is a two-bearing shaft, the two bearings being more than equivalent to the three bearings in older designs and permitting of easier re-

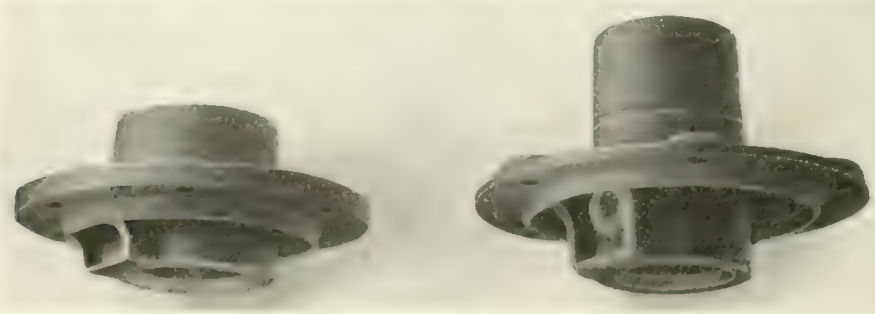


FIG. 3—COMPARATIVE VIEW OF OLD AND NEW BEARINGS

alignment after renewal of bearings. A comparative view of the old and new bearings is given in Fig. 3, while Fig. 4 shows the completely machined shaft, old and new designs respectively.

The gear is a herring-bone, fine-tooth, six spoke, semi-steel gear, the two halves being solidly riveted together. It is held on the shaft by a large castle nut which is prevented from backing off by a cotter pin. The taper of the crank shaft is such

as to permit of easy pulling-off of the gear. The gear case is split vertically, the cover making half of the gear case. This construction enables ready assembly and easy and complete inspection. The cover is light and requires only seven ½ inch bolts.

Lubrication—Lubrication is obtained by means of connecting rods and cranks splashing in the crank case oil, sufficient oil working along the gear end bearing and into the gear case to lubricate the gear and pinion. As there is no direct connection for the oil to get over into the gear case, there will never be more than a small amount of oil in the gear case, so that there is no difficulty in keeping the joint between halves of the gear case oil tight. The small quantity of oil in the gear case prevents heating due to churning of the oil in gear case and makes flooding of the motor impossible.

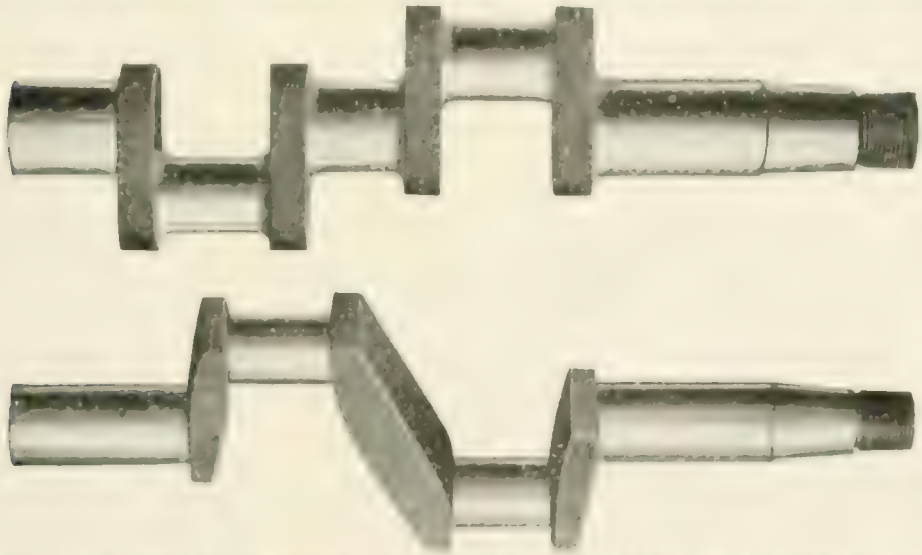


FIG. 3—COMPARATIVE SIZES OF THE ARC NEW TYPE AND OLDER SHAFTS.

The crank case is filled either from the top by removing the crank case cover or through a very conveniently located oil fitting near the pinion. As the gear turns, oil is carried up over the pinion and works into the rear motor bearing cavity. Thence any excess drains through a cored cavity into the crank case. Thus, the rear bearing of the motor is automatically oiled. The armature bearing on the commutator is filled separately. Both armature bearings are single ring bronze bearings. The dip of the rings into the oil is just sufficient to give ample lubrication without drawing up an excess of oil which would tend to creep along shaft. Special precaution has been taken in this design to prevent oil from reaching the commutator or fields.

The quantity of oil used has been reduced to a minimum by

the use of this self-contained lubricating system, and the elimination of joints which should be oil tight. A still further point of vast importance to the operator is the prevention of oil passing into the brake system. A very small amount of oil is required to lubricate the cylinders, pistons and wrist-pins; and an exceedingly small amount of oil getting past the rings each stroke will, in the course of a few days, amount to a quantity of oil which would be prohibitive, both because of the actual loss and because of the detrimental effect on hose and other air using apparatus. This passing of oil has been entirely overcome by the new construction. Further, the loss of oil from the crank case in the form of vapor from any cause is prevented by coring a passage from the top of the crank case to the suction of the compressor. A tapped crank case vent is also provided, should a railway operator wish to pipe this vent away from the compressor. The cored passage from the crank case to the suction not only prevents the loss of any oil, but protects the crank case oil from dirt by the same strainer or dust collector which protects the in-take of the compressor. The discharge from the crank case, being connected in the in-take of pump, does not reduce the cylinder efficiency of the compressor to an appreciable degree even when operating at maximum pressures. It absolutely prevents annoying vaporizing formerly so prevalent in worn or poorly maintained compressors.

Motor Construction—On account of the large demand for air outside of the brake system, and also of the desire to keep down the total weight of the compressor, it is necessary to have sufficient motor capacity to permit of practically continuous operation of the compressor without overheating the motor. The temperature rises in all parts of the motor from continuous running at from 65 to 90 lb. gage pressure are very moderate. Armature leads are protected from breaking by slotting the commutator bars sufficiently to take the insulated wire, so that the portion of the wire which is most likely to break is supported by the bar itself, just back of the narrower slot for the soldered lead. Commutators have mica insulation undercut and well rounded corners. Large creepage distances are provided and every precaution taken to prevent oil from getting onto the commutator. All cotton covered armature coils and field coils are insulated under the vacuum process. This treatment makes the coil a solid mass, water and oil proof. The completed armature is also impregnated as a whole.

The fields of this particular motor, however, are wound with enamel covered wire, giving maximum radiation and minimum copper loss.

Standard railway motor practice is followed throughout, including flat steel spring washers to prevent field coil chafing. Brush studs have a fixed location, being insulated with mica bushes, extra creepage distance being obtained by fibre sleeves. This construction is very strong both mechanically and electrically and not affected by any degree of heat obtainable in the motor. The brush holder box has a small lug on its side, so that the spring can be pushed to one side and caught on this lug, permitting the removal of a brush with one hand. Leads are insulated from castings by small fibre blocks, both leads being brought out of the motor directly below the door. This construction makes it practicable to run conduit into the motor if desired. The cover over the end of the armature shaft at the commutator end is in the form of a threaded cap and not a plate. It is easily removed for inspection of oiling ring and makes an oil tight joint.

Armature Removal—In order to remove an armature it is necessary to remove only seven bolts from the gear case and the four bolts from the front bearing housing. After loosening the two remaining cap screws which hold the brush holder stud clamps, the holder may be swung back out of the way. Then, after blocking the gear and pinion so that they cannot turn, the lock nut from the pinion can be removed. Then, by means of the standard pull-off attachment, the armature can be forced out of the bearing. The armature can then be lifted out.

Suspension—The compressor is arranged for both three-point and four-point suspension, the object of the four-point being to suspend this machine in the same place as that occupied by previous types of compressors, if desired. The use of the three-point suspension, however, is preferred, as it makes it possible to decrease the weight of the suspension and give a more uniform distribution of weight. The cushion pockets are still used with the wedges, so that the compressor may be lowered from the car with the same ease as formerly. In order to facilitate handling of the compressor when shopped, a tapped hole for an eye bolt is provided at a point very nearly in line with the center of gravity of the machine.

Strainers—As the length of service which a compressor gives is determined largely by the cleanness of the air taken into the

pump, and the consequent freedom of the lubricating oil from foreign matter, it is very important to have a good strainer or dirt collector. For ordinary conditions, a hair strainer of ample proportions piped up near the roof of the car serves every purpose. A more recent construction is one in which the efficiency of the dust collecting device is not decreased materially by the passage into it of considerable quantities of dust. By the use of this device, the air passing into the compressor is practically free from dust and grit, and as the gear case vent is protected by the same device, the machine is practically dust-proof, and will operate for long periods of time without the renewal of oil.

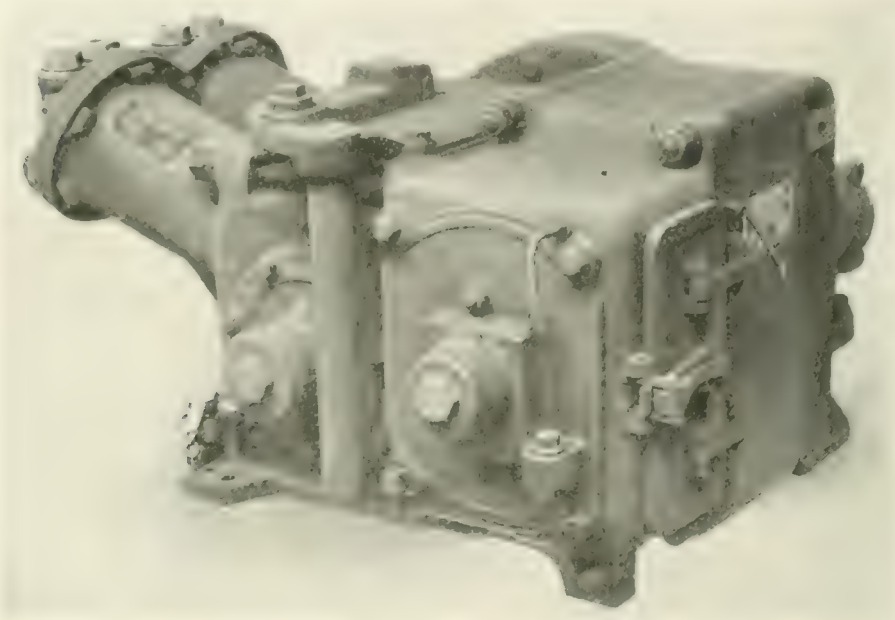


FIG. 5—IMPROVED TYPE OF MOTOR-DRIVEN COMPRESSOR UNIT

D-L TYPE COMPRESSORS

In order to meet the requirements of severe service, the type "D-L" compressor has been brought out to incorporate the best construction, regardless of cost. The chief points of difference between this type of compressor and previous types are as follows—

1—Elimination of bed-plate.
2—Use of long tie bolts to fasten motor and compressor together.
3—The use of slant cylinders.
4—Bushed cylinders.
5—Increased capacity motor.
6—Laminated yoke for motor.

This compressor, shown in Fig. 5, has a gear case split nearly

horizontally, so that there can be no leakage of oil. The crank shaft was very materially strengthened, the two outside bearings being sufficient alone, although a middle bearing was arranged for, this bearing not being babbitted unless called for. The diameter of piston was decreased and the stroke, connecting rod and piston were all lengthened. The cylinders were bushed to obtain a harder and more uniform grade of material for the cylinder walls and to make it possible to re-bush cylinders more readily and accurately. The slant cylinders are for the purpose of reducing the clearance around the valves. This decreased clearance

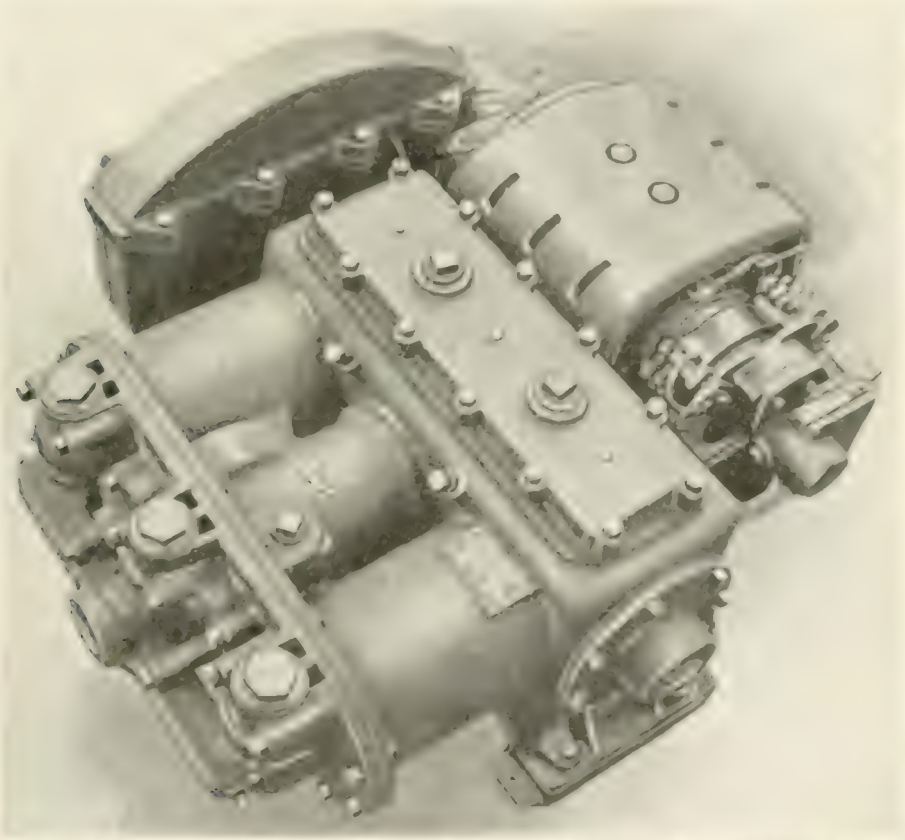


Fig. 6.—Three-cylinder Compound Motor-driven Compressor Unit

gives maximum cylinder efficiency. Although the over-all efficiency of this compressor and the actual capacity due to ability to run continuously are very materially increased, the over-all weight on the car is less than in older designs. The motor for this compressor was increased in size so that it would stand continuous operation without overheating, the winding being arranged for a maximum of 750 volts.

For heavy duty, high pressure service on locomotives operating at voltages up to 750 volts, a three cylinder compound compressor is used, as shown in Fig. 6. This compressor is provided

with intercooler between the high and low pressure cylinders and delivers air at pressures up to 160 lbs. per square inch at maximum efficiency with minimum heating. The motor starts without resistance up to 750 volts and will operate continuously against 120 lbs. pressure. There are two low pressure cylinders $8\frac{1}{4}$ inches in diameter and one high pressure six inch cylinder.

The motor runs at 800 r.p.m. The solid cast steel yoke is open at both ends and has four field coils. Motor and compressor are mounted on a bed-plate. Standard railway motor practice is followed. Brushes are particularly accessible for locomotive service, being on the upper side of commutator. There are two studs, each brush holder carrying two carbons in separated boxes, each carbon having its individual spring. Compressor lubrication is by means of the usual splash system. Both motor bearings,

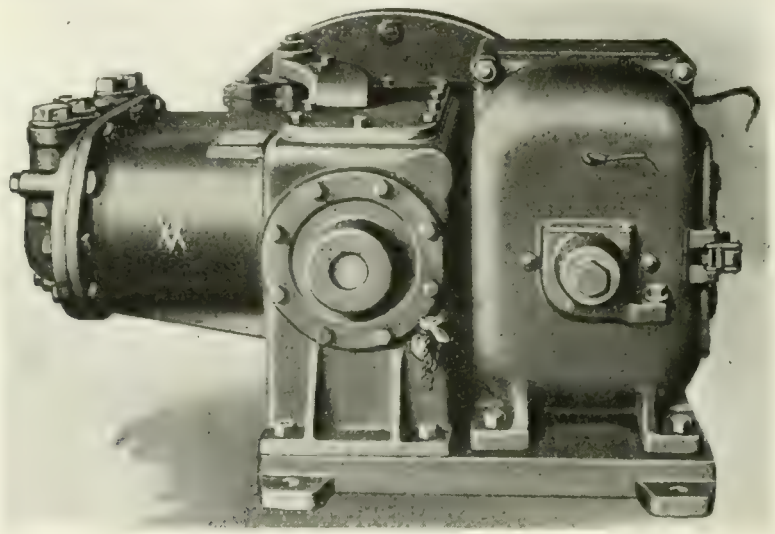


FIG. 7 — COMPRESSOR SET WITH SPECIALLY INSULATED MOTOR

however, are waste packed. The crank case cover contains a large amount of curled hair through which the venting air passes, to prevent vaporization and loss of oil.

SPECIALLY INSULATED COMPRESSORS

For certain classes of locomotive service where pressures are not excessive, a single stage 50-foot compressor has been used. The motor, in order to permit of continuous operation if necessary, is wound with heat proof wire and insulated with heat proof materials. This compressor unit is shown in Fig. 7. The motor is enclosed and has a laminated yoke and strap wound fields. It will drive the compressor continuously without injury to the insulation. Although rated at 600 volts it will operate satisfactorily up to 750 volts. The pole pieces are dovetailed and wedged into the yoke,

making a very solid though easily dismantled construction. The motor end brackets include the bearing housings, as shown in Fig. 8, so that perfect alignment is secured.

HIGH VOLTAGE DIRECT CURRENT COMPRESSORS

The raising of the line voltage on certain roads from 600 to 1200-1500 volts, has necessitated new designs in the compressor

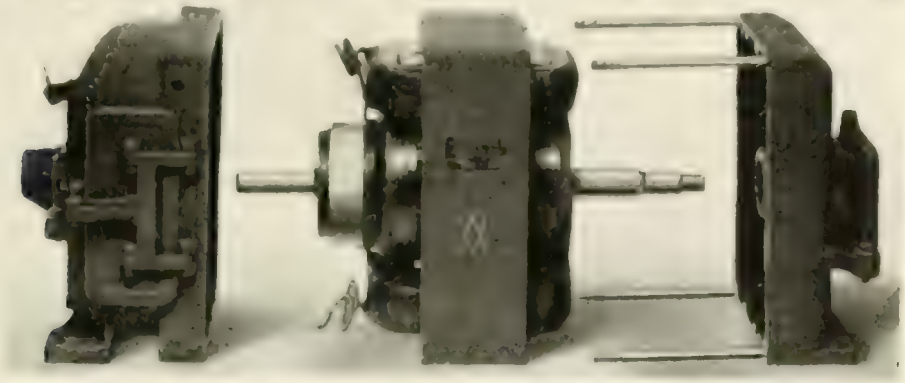


FIG. 8—DETAIL VIEW OF MOTOR SHOWN IN FIG. 7

motors, and this increase in voltage, together with the necessity for operating on 600 volts in towns and cities and on 1200 volts or 1500 volts in the country, makes necessary the use of double commutators and extra precautions in the mater of thickness of insulation and creepage distances. The necessity for as much compressed air within city limits, where the voltage is 600 volts or less, as is required in those sections where the voltage is 1200 or

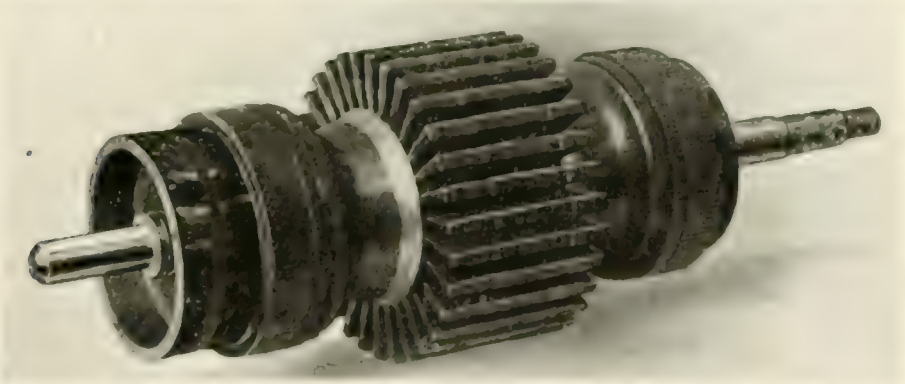


FIG. 9—CORE AND COMMUTATORS OF HIGH VOLTAGE DOUBLE COMMUTATOR ARMATURE

1500 volts, requires new arrangements of windings and connections. A view of the core and commutators of an armature for this service is shown in Fig. 9.

Special Compressors—For locomotive service two special forms of compressor construction have been used.

1—The combination of dynamotor and compressor in one unit. This construction is particularly desirable where two blowers and two compressors are required. This is also a very attrac-

tive proposition for cars, as there is a considerable gain in weight over the use of a separate dynamotor and compressor. These dynamotor compressors are built in 25, 37 and 50 foot displacement capacities

2—Two 600 volt compressors mechanically connected for series operation on 1200 volts and for multiple operation on 600 volts. This unit consists of two 600 volt compressors mounted on a large bed plate as one unit, and mechanically connected by a multiple disc clutch. The coupling is made by a pair of pinions and a shaft on the upper half of the compressor gears. This method is nearly equivalent to connecting the two armature shafts direct. It has the advantage, however, of maintaining the parts

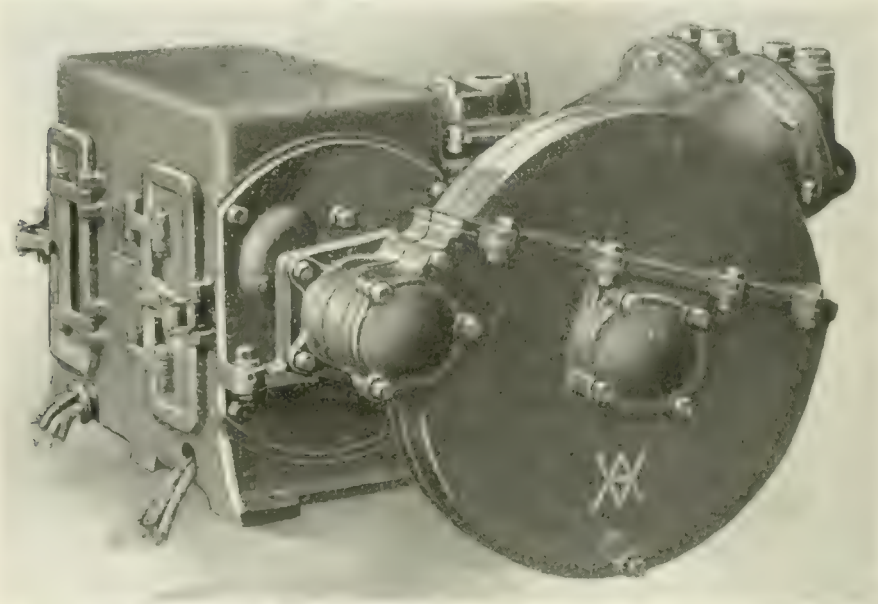


FIG. 10—MOTOR-DRIVEN COMPRESSOR SET FOR USE ON 1200-1500 VOLT AND 600-VOLT DIRECT-CURRENT LINES

of the compressors and motors, except gear case cover, standard and requires only that certain parts of the coupling itself shall be in pairs.

SUMMARY

While high efficiency has been maintained in this compressor development, those other qualities of highest importance to the railway operator have been given even more consideration. These are, ability of a machine to stay on the road regardless of weather or voltage conditions, long life without repair or renewal, ease of inspections and handling in shops, quietness of running and economy in oil consumption. The satisfactory fulfilment of these desirable elements should be of vital interest to railroad operators. The decrease in weight of equipments and actual cost of compressed air used, due to higher efficiency and shorter time of running as well as longer life of parts means decreased operating cost.

SIGNAL EQUIPMENT OF THE PIEDMONT SYSTEM

WITH SPECIAL REFERENCE TO THE SECTION BETWEEN CHARLOTTE, N. C., AND HOSKINS YARDS

L. FREDERIC HOWARD
Chief Engineer, Union Switch and Signal Company

IN this installation* all signals are operated by single-phase alternating current delivered at 60 cycles, 2200 volts. The power, both for the propulsion of cars and for the signals, is obtained from the transmission lines of the Southern Power Company. The cars and locomotives are operated in the main from 1500 volt direct current trolleys, although there are sections through cities, etc., where the trolley voltage is 500-600 volts. The service includes passenger, freight and express traffic. Certain parts of the line are used in common by the cars of the Piedmont system and by local city cars, such as those of the Charlotte Electric Company. Heavy interurban cars are operated singly or in trains. In the section between Charlotte and Hoskins the operating speed is about 35 miles per hour while 60 miles per hour is obtained south of Hoskins. Freight trains are handled by electric locomotives. City cars at 20 minute intervals operate at all times of the year between Charlotte and Hoskins with numerous extras to handle the summer traffic to and from Lakewood Park. These cars operate at a maximum speed of about 30 miles per hour. A part of the line is double track and cars on this section may be operated under two minute headway.

The arrangement of signals for this section is indicated in Fig. 1. At the Hoskins sub-station, power for the signals is obtained from high voltage transformers through automatic switches. Rotary converters supplying power for the operation of the cars are also located in the sub-station. The 2200 volt signal lines are carried on special signal cross-arms attached to the regular trolley poles. At signal locations the voltage is reduced from 2200 to 10 volts for the track circuits and to 110 volts for the lamps, and for the signal relays and switch indicators by the use of double secondary transformers. The transformers, lightning arresters, fuse blocks and adjustable reactance units are mounted on short poles as required near signal indications. The current supplied to the

*A general description of the Piedmont System is given in this issue in the article by Mr. H. D. Murdock.

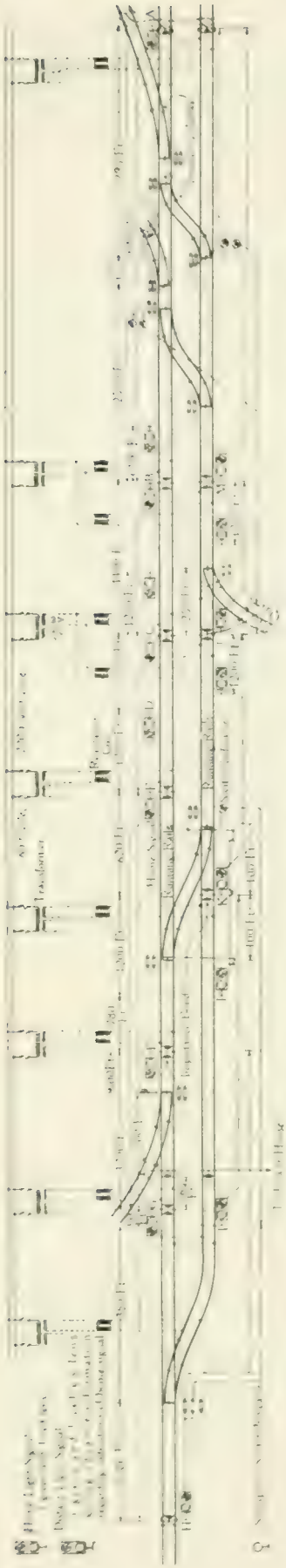


FIG. 1.—ARRANGEMENT OF ALTERNATING-CURRENT BLOCK SIGNALS FROM CHARLOTTE TO HOSKINS YARDS

track circuit is limited by adjustable reactance coils instead of resistances, thus affecting a considerable saving in power. The alternating current supplied to the different track circuits is segregated by insulation joints placed between rails at the limits of the block sections, the propulsion current being provided with a path around these joints by impedance bonds of comparatively low ohmic resistance but high reactance. These bonds, while permitting the direct propulsion current to flow without obstruction around the insulated rail joints, oppose the flow of the track signal current. The impedance bonds are mounted on the ties between the rails and are of 350 ampere capacity per rail. The use of alternating current for the track circuit of course eliminates all interference by stray direct current. The current delivered to the track circuit is maintained normally at a constant voltage without particular attention and rarely needs adjustment. This fact constitutes a considerable improvement over the use of batteries which require considerable attention for maintenance and renewal. By the use of the two rails as parts of the alternating-current circuit, signal indications are operated by the connecting together of the two rails electrically whenever a car or train is passing through a given block.

The short lines at right angles to the heavy lines representing the rails in Fig. 1, indicate the limits of the track circuits. The presence or absence of a car in each section determines the indication given by the signals through the de-energization or energization of

a relay in the track circuit. These track relays, as well as the other relays used, are controlled entirely by alternating current and are immune to direct-current, and hence the propulsion current cannot interfere with the signals. The division between circuited track and uncircuited track is indicated by a small cross line across the rail with another smaller line at right angles to it. The dot and dash lines in Fig. 1, extending from the signal symbols and terminating in arrow points indicate that the signal is controlled by the corresponding parallel track extending from a point opposite the base of the signal symbol to the arrow point.



FIG. 2—VIEW OF SIGNALS SHIELDED BY METAL HOODS

Stub pole on the left carrying transformer and other equipment.

At switches, sidings, and cross-overs, protection is provided by carrying the track circuit a certain distance beyond the switches so that in case a car comes within fouling distance of the main track, the fact will be indicated by the proper signal. Small indicators are placed at switches to show, by the position of their semaphores, when a train is approaching within a block. Switch boxes which control the signal indications are attached to the switch points at each switch, so that the opening of any switch places the signal protecting that switch at danger.

One of the distinguishing features of this installation is the fact that it is the first instance in which light signals have been used in-

stead of semaphores on an installation of any size. Two 25 watt, 110 volt tungsten lamps, provided with an eight inch lens, furnish the light for each signal indication. The signal lamps and metal hoods are mounted on iron posts, with the relay cases made as integral parts of the posts. A red light is used to indicate "stop, not less than 30 feet from the signal, wait one minute and then proceed with caution to the next home signal, expecting to find track obstructed"; a green light for "proceed at speed, block ahead is clear"; and a yellow light for "proceed at caution, expecting to find the next home signal at stop or red."

The use of light signals to give a daylight indication, as well as for night service, is made especially difficult in the case of the



FIG. 3—VIEW OF LIGHT SIGNAL, RELAY BOX OPEN

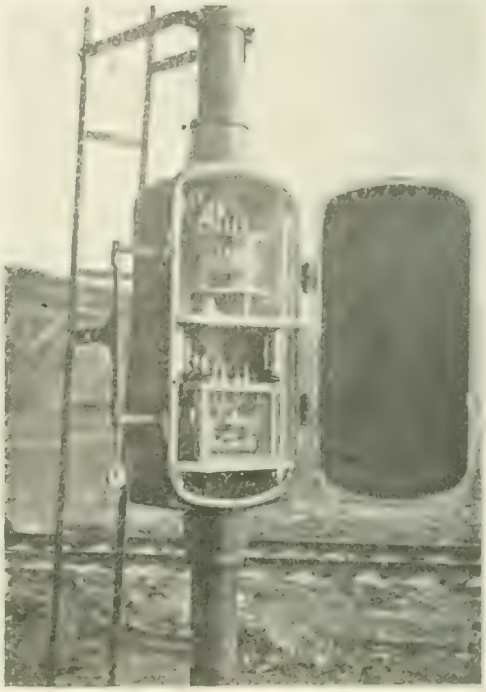


FIG. 4—DETAIL VIEW OF RELAY BOX

green indication because, if reflectors are used giving a good range of visibility, there is danger of a false indication due to reflected light from outside when the lamps are not lighted, and if too high a candle-power is used to secure the desired range, the quality of the green for night indication is impaired.

It was found that the desired results could be secured by the use of a large background, which was obtained by flaring the hood at the sides and placing a vertical visor at the top, or by the use of an extension from the sides of the lamp. As the green lens is the one from which it would be dangerous to have enough external

light reflected to give a false clear indication it is placed well up in the hood above the red light. Hence the use of the visor to give background above the green.

It has been found that even in bright sunlight the red and yellow lights are readily distinguishable at 2000 feet and the green lights at 1500 feet. At night the indications are seen clearly at even greater distances. The glow of the red light is visible in fog for long distances even when a semaphore signal would be invisible. At the entrance of each block, home signals with red and green lights are placed and distant signals with yellow and green lenses are located from 1200 to 1600 feet in advance of the home signals.

The advantages, from a maintenance point of view, of a signal system of equipment with light signals is at once apparent when it



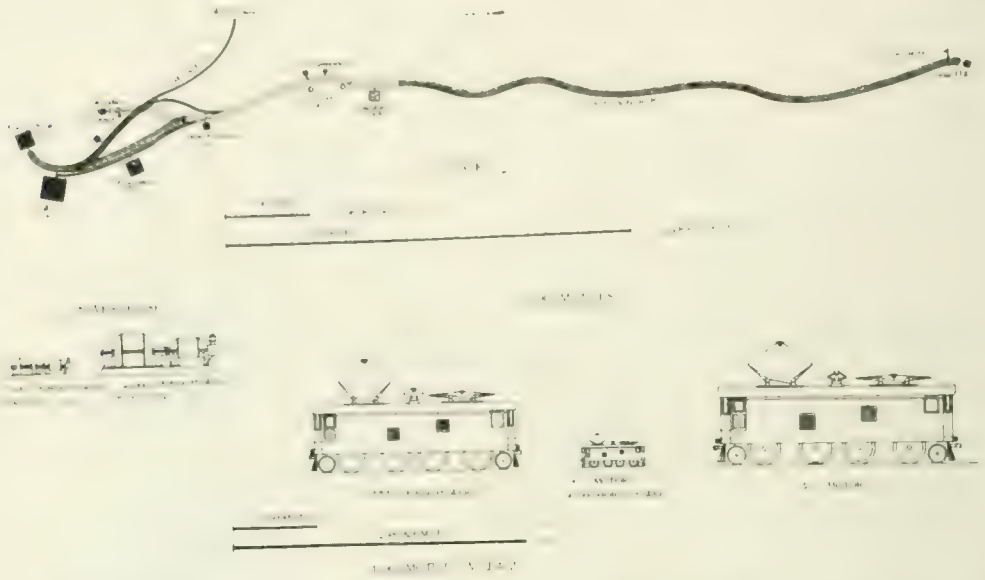
Fig. 3.—Type of the switch indicator.

is considered that the only moving parts in such a system are the relays. Practically the only regular maintenance required is the replacement of lamps and of fuses blown out during severe electrical storms. It is true that the range of visibility against the sky background is not so great as of the semaphore. On the majority of trolley roads, however, the perspective consists of poles, cross arms and span wires, and under these conditions the light signal is oftentimes superior to the semaphore as regards visibility.

PROGRESS ON NEW HAVEN ELECTRIFICATION

THE original electrification of the New York, New Haven & Hartford Railroad included the four track line from Woodlawn (where the New Haven trains from the Grand Central Station, New York City, leave the tracks of the New York Central) to Stamford, a distance of about 22 miles. Extensions recently completed, or now under construction, will complete the electrification of all lines West of New Haven.

The New Haven service, both freight and passenger, and that of the New York, Westchester & Boston Railway, will be operated from the Cos Cob Power House, just west of Stamford.



A statement of the conditions at the beginning of the present year and the anticipated conditions next year were recently presented by Mr. W. S. Murray, electrical engineer of the system. The figures, as given in Table 1, are presented graphically in the accompanying chart.

TABLE 1

	1912	1913
Miles of Single Track	114	552
Capacity of Power House, Horse-Power	21 000	46 000
Number of Locomotives	41	151
Locomotives, Horse-Power	41 000	128 800
Locomotive Mileage	1 569 648	5 489 856

The electrification of the New Haven tracks from Boston to Providence is now under serious consideration. The distance is slightly more than 40 miles. When this is completed, over half the distance between New York and Boston will be covered by electric locomotives.

ECONOMIES IN RAILWAY OPERATION*

F. E. WYNNE

PROBABLY nowhere has the search for efficiency been more active than in the electric railway field. Every part of the equipment has been studied with the greatest care to increase its life and reliability and decrease the cost of maintenance. Not only has there been a great increase in reliability, but the cost of inspection and maintenance has been reduced to a degree that makes it cheaper to scrap old equipments than to operate them. It is intended to discuss in this paper some of the proposed means for saving power on electric railroads and to clear up, if possible, some of the misunderstandings that exist at the present time.

REDUCTION IN WEIGHT

In the development of electric railways, the evolution of cars and equipments from the old horse cars to the modern double truck city cars and the high speed interurban cars has been attended by much grief and loss. The development was so rapid that the only method possible to pursue was to build the car and equip it, using the best judgment available in proportioning the parts. Where parts broke in service, they were usually strengthened by increasing weight and section, regardless of the actual cause of the break which might have been in something entirely different. This of course resulted in designs which were unnecessarily heavy. It is the part of good designers and conservative engineers to redesign them, distributing material where necessary for strength and cutting out as much unnecessary material as possible. It is astonishing what results have already been obtained in this line. The use of high-grade materials and pressed steel shapes with new types especially fitted for them will still further reduce weights of car bodies and trucks.

Motors—The weight of motors may be reduced by very careful designing; by the use of high-grades of metal to give the necessary mechanical strength with smaller sections; by the use of higher grades of insulation which will allow operation at higher temperatures and thus permit the use of smaller motors; by the use of forced ventilation, and by increasing the armature speeds.

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*From a paper read before the Baltimore section of the American Institute of Electrical Engineers.

Improved Design—The first method of cutting the weight, that is, by eliminating all useless weight, is a quite obvious one, and has been followed to a greater or less extent for years. It is now being worked to the limit, and it is safe to say that all motors which are designed hereafter will have a minimum of useless weight in them.

High Grade Metals—There are now very few motors that have cast iron in them where weight would be saved by the use of malleable iron or of steel. Heat-treated steel is also used in some cases for shafts. The possible reduction of weight in shafts is very limited since the reduction in diameter reduces the stiffness in the shaft very rapidly, and even if the shaft is of the high grade material, it is not safe to permit the deflection. Great improvements have been made in steel castings in late years. Thinner sections can thus be used than has been possible to cast heretofore.

High Grade Insulation—A certain amount of increase in capacity from a given size of motor may be obtained by the use of heat-resisting insulation. It has been common practice to use mica insulation for armatures and asbestos insulated copper for field coils. Asbestos insulation, however, must be handled with greater care than cotton or similar fabrics, as asbestos is weak mechanically, and armatures are more liable to short-circuit. The net gain in capacity by using high-grade insulation is somewhat reduced because better insulating materials are poorer heat conductors and a given load produces higher motor temperature than with poorer insulation. The limit to the temperature in motors at present is the melting point of tin solder. Very little increase in temperature above the present limits will be possible until a soldering material with higher melting point is produced. Tin melts at about 225 degrees C. This seems like a good margin to give a motor which is supposed to operate around 75 to 100 degrees C.; as a matter of fact, the sudden heavy loads on motors, which do not last long enough to heat up the entire armatures, will last long enough to melt the solder or at least soften it to a point where it is thrown out by centrifugal action. Any increase in capacity produced by increased temperature will be obtained simultaneously with lower efficiency of the motor, since in most cases a small motor operated at heavy overloads and high temperatures will have a lower efficiency than a larger motor operated

in the same service. Thus part of the saving which is effected by the use of a motor of slightly less weight is lost in the decreased efficiency of the motor.

Forced Ventilation—The fourth method of increasing the output, namely by forced ventilation is quite effective. It increases the continuous capacity of motors, which ordinarily is not more than 45 to 50 percent of the one-hour current rating, to 65 to 80 percent of the hour rating. A great deal may be accomplished by the use of fans on the armature with openings through the armature. This establishes a circulation of air inside of the motor, thus bringing the air in contact with the inside of the motor frame which can radiate the heat. The radiating surface of the motor may be increased by the use of ribs cast on the outside of the frame.

High Armature Speed—Increasing the armature speed is permissible where it can be done without sacrificing economy of operation. A certain frame is adapted to give a certain torque at the armature shaft. This will usually be somewhat greater with a low speed winding than with a high speed winding, but roughly speaking, it is a constant, and the horse-power rating of the motor will consequently be increased as the rated speed is increased.

An equipment with a high-speed gear ratio on city cars will use more power than the same equipment would take if supplied with the maximum gear reduction. The recognition of this fact has resulted in a wholesale change in gear ratios on the cars in many of our large cities, notably Brooklyn, Chicago, Baltimore and Pittsburgh. For ordinary city service a motor operating at a full-load armature speed of between 450 and 550 r.p.m., when supplied with its maximum gear reduction, will give the greatest economy in operation. Motors operating at 600 to 700 r.p.m., even if supplied with maximum gear reduction, will require more power on account of greater rheostatic losses in starting. Consequently, it is essential that care be used in selecting motors, not simply to pick the strong motor having the lightest weight, but to select one which has the correct speed and torque characteristics. It will be found that far more can be saved by gearing the motor for the most economical speed than by any reduction in the weight. It is not at all uncommon to save 15 or 20 percent in power by a change in gear ratio, while the weight of the motors

alone cannot be changed by increasing the speed so as to affect the total car weight more than five percent. Further, any increase in armature speed above the economical speed will not reduce the weight of motor required for a given service, for the root-mean-square current of the high-speed motor will be greater than that of the low-speed motor in proportion to the increase of speed, which is proportional to the increase in capacity. Therefore, a given service will produce equal heating in motors of the same weight but different speeds with the same gear ratio.

Control—The weight of control apparatus may be reduced by improved design of parts, by more efficient arrangement of switches, by more efficient use of resistance, and by better location of apparatus on the car.

Improved Design—High grade material may be employed to advantage in control apparatus. The greatest reduction in weight will probably be effected by the use of structural and sheet steels in place of cast iron.

Improved Arrangement—Where a number of similar operations are to be performed by a number of similar units of apparatus there is the possibility of accomplishing the same result with widely different numbers of units. Reducing the number of units required to a minimum is a matter of development and frequently there is a chance that some new combinations of units may be discovered which will employ fewer units than required by present standards and so reduce the weight of the control equipment.

Better Use of Resistance—By using the same sections of resistance in different combinations for different controller notches, not only may the weight of resistance be reduced, but the number of switches employed may be decreased and the main wiring lessened.

Better Location of Apparatus—The amount of wiring may be reduced to a minimum by carefully arranging the apparatus under a car.

Two-Motor Equipments—In many of the large electric railways and steam railroad electrifications, the advantages of two-motor equipments in place of four-motor equipments have long been appreciated. Where only half of the wheels are available for adhesion, of course the conditions of grade and climate must be such that from 60 to 75 percent of the total car weight will

permit developing sufficient traction for all the requirements of the service. With two motors, the total equipment weight per horse-power is from seven to 30 percent less than with quadruple equipments. A further gain may be made in the trucks. In addition to having a higher weight efficiency, two-motor equipments have higher electrical efficiency and reduced first cost and cost of maintenance.

PROPER GEARING AND ARMATURE SPEED*

Probably five to ten percent of all the power used for propelling electric cars and trains could be saved by correct gearing. The maximum gear reduction varies from 3.5:1 to 5:1, depending upon the power of the motor. The armature speed at the 500 volt rating of a motor varies from 500 to 650 r.p.m. Therefore, with maximum reduction and minimum wheel diameter, the car speed at full load of the motors varies between about 10 to 18 miles per hour. Even motors of the same power are built for such speeds that with the same gearing, the car speeds differ by as much as 25 percent. The opportunity for incorrect motor application, particularly where stops are frequent, is therefore apparent.

City Service—In city service there is very little running at full speed. The essentials for maintaining the schedule are rapid acceleration and braking. In most cases there is no difficulty in keeping cars on time with the motors geared with the maximum reduction. Under such conditions a motor of low r.p.m. with the same gear reduction, will either give the same rate of acceleration with less current or with the same current it will give a higher rate of acceleration than the motor of higher r.p.m. Both of these features tend to reduce the power consumed.

As an illustration compare the shorter runs in Figs. 1 and 2. In each case train, grade and curve resistance has been taken at 22 lbs. per ton. The slow-speed motor of Fig. 2 takes the same accelerating current as the high-speed motor of Fig. 1. Because of the quicker start with the low-speed motor, the heavy current does not last so long, the same amount of coasting is obtained, and the brakes are applied at a lower speed. The gain in power

*See article by Mr. N. W. Storer in the JOURNAL for September, 1908, p. 510; and by the author in the issue for July, 1906, p. 360

consumption in favor of the slow-speed motor is 10.9 percent. Part of this saving is the result of lower rheostatic losses and the balance is due to the smaller amount of stored energy wasted in the braking process. These curves will also serve to illustrate the effect of gear ratio. The high-speed motor corresponds to the slow-speed motor with a 4.43:1 gear reduction. However, in this instance the car weights should be the same so that the difference in favor of the slow-speed gearing is even a little greater than the 13.8 percent saving indicated by the watt-hour per ton-mile values of the figures. Figs. 1 and 2 show that the two motors make the schedule equally well. The higher ac-

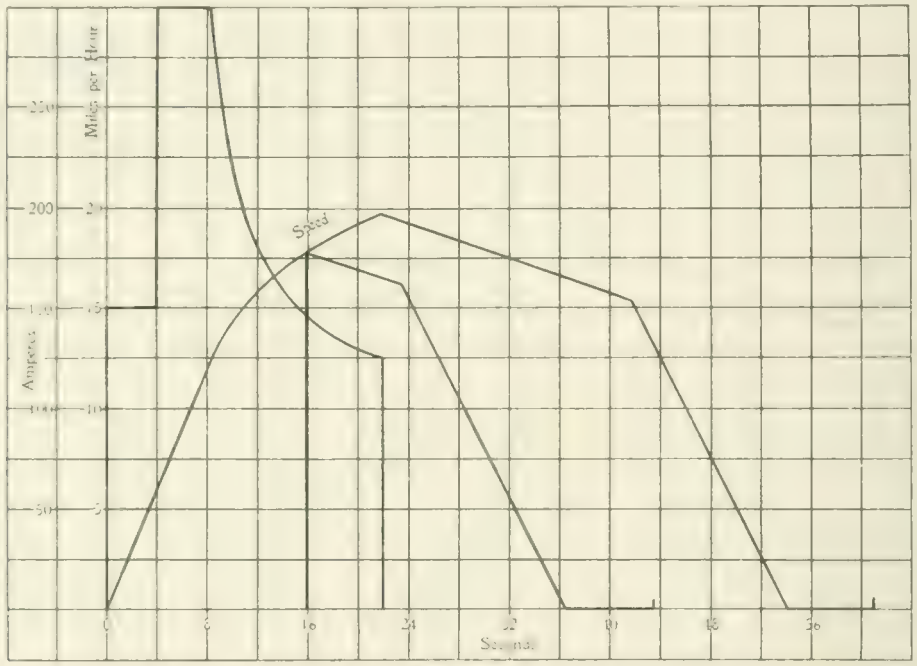


FIG. 1

celeration is obtained with the slow-speed motor without subjecting the equipment to any heavier current. The amount of coasting is practically the same, so that if the runs were made without any coast, the times would be the same. The high-speed motor is already slightly overworked, so there is no hope of making a faster schedule by forcing its rate of acceleration up to the value which is safe with the slow-speed motor. Neither can the high-speed motor take advantage of more rapid braking to increase the schedule speed. However, since the slow-speed motor is not yet worked up to its full capacity, it can use faster braking to a certain extent without being overloaded.

Now consider whether the saving due to less weight will

make up for the loss in power consumption. If the car under consideration makes 30 000 miles annually, the car with light high-speed motors at 4.21 kw-hr. per car-mile will consume 126 300 kw-hr. annually while the car with slow-speed motors will consume 112 500 kw-hr. The annual saving is 13 800 kw-hr. At one cent per kw-hr. this amounts to $138. At five cents per pound per year, the high-speed motor car would save $100 annually. The net saving is $38.00 annually in favor of the slow-speed motor.

If the heavier car consumed the same energy per ton-mile (145 watt-hours) as the lighter car, the latter would save in energy

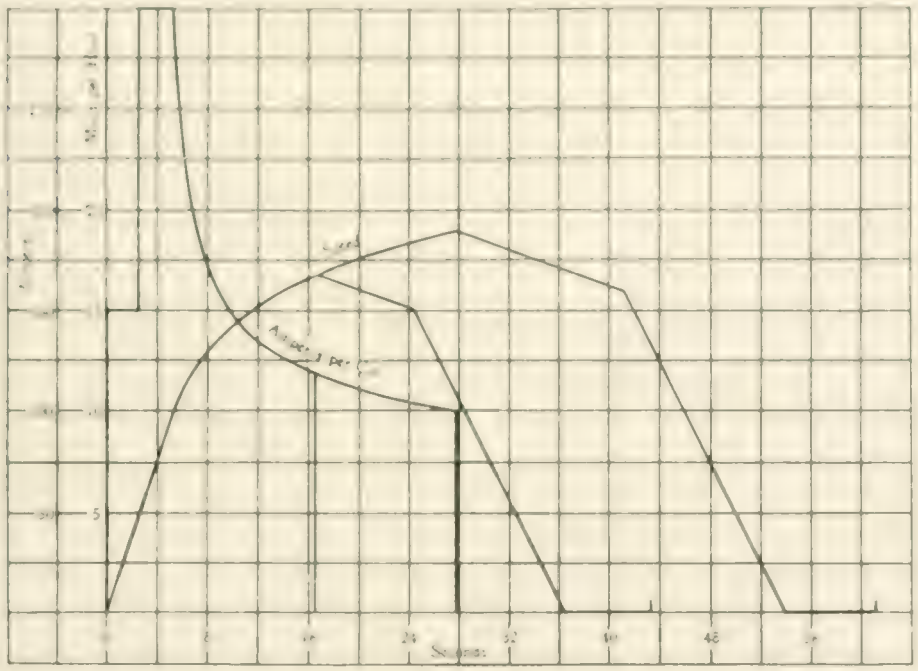


FIG. 2

4350 kw-hr. annually. Hence $43.50 of the $100.00 annual saving credited to the light motor above is not really obtained and the actual net saving for the slow speed motor is $81.50 per year.

Combined City and Suburban Service—In this class of service the same general principles hold as for city service. The possibility of using high speed is only slightly greater than in city service as the stops are still comparatively frequent.

For example assume that the operation of a certain line comprises six miles of city running with nine stops per mile and six miles of suburban running with five stops per mile. The minimum running time without any coast is 68.8 minutes for the slow-speed motor and 68 minutes for the high-speed motor, a difference of

0.8 minute or 1.16 percent. On the basis of a schedule time of 81 minutes for the run one way and operation of the two motors as shown in Figs. 1 and 2, the power consumption with the high-speed motor is 42.54 kw-hr. per trip and with the slow-speed motor is 30.0 kw-hr. per trip, the latter saving 0.2 percent of the energy required by the former.

In this class of service the annual car-mileage is generally higher than in city service only, on account of the longer trips, somewhat higher average speeds, and smaller difference between the average and maximum number of cars required at different times of the day and year. Assuming 40 000 miles per car yearly and power at one cent per kw-hr., the saving by using the slow-speed motor instead of the high-speed motor amounts to $46 annually.

Interurban Service—Practically all interurban railways enter one or more large towns or cities over tracks laid in the streets. This condition generally requires slow-speed running and therefore this part of the service is most economically maintained by the slowest speed gearing suitable for the other service. Many of these railways give both local and limited service. The local service, because of the more frequent stops, will work the motors more nearly up to their full capacity than will the limited service. In order to minimize the size of the equipment and get the maximum economy of power, the gear ratio should be selected on the basis of the local service, and the limited schedule adjusted to suit the equipment and gearing best adapted to the local service. If a high speed limited schedule is taken as the basis of choosing the gear ratio, one of two evils frequently results: —1—A small equipment, geared for abnormally high speed and just able to maintain the limited schedule nicely, is selected, with the inevitable result of overheating the motors in local service; or—2—a large equipment, geared to maintain the limited schedule and yet of sufficient capacity to perform the local service without over heating, is chosen with the result that the power consumed in local service is excessive and equipments are heavier than need be.

In the last analysis we believe that the extra cost of excessively high speed limited service is rarely equalled by the additional revenue obtained on account of the excess in speed over what could be secured with equipment geared for moderate speed.

Table II shows that the power consumption per car-mile for local service is 2.4 kw-hr. with 75 hp motors and 2.7 kw-hr. with

90 hp motors and for limited service is 2.03 kw hr. and 2.30 kw hr. with the 75 hp and 90 hp motors respectively.

CORRECT OPERATION

By correct operation is meant the use of proper accelerating and braking rates so as to obtain the greatest amount of coasting consistent with the particular equipment used in any given service.

Acceleration—It is frequently found, where a road is operating under a fairly easy schedule, that the motormen will accelerate rather slowly and perhaps operate with the motors connected in series for a considerable part of the time. So far as comfort is

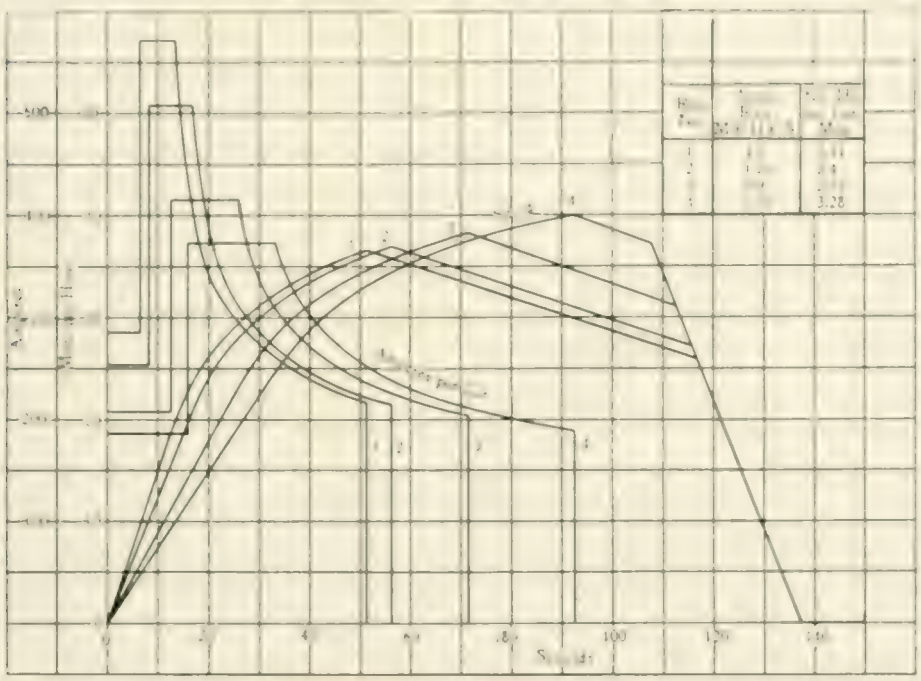
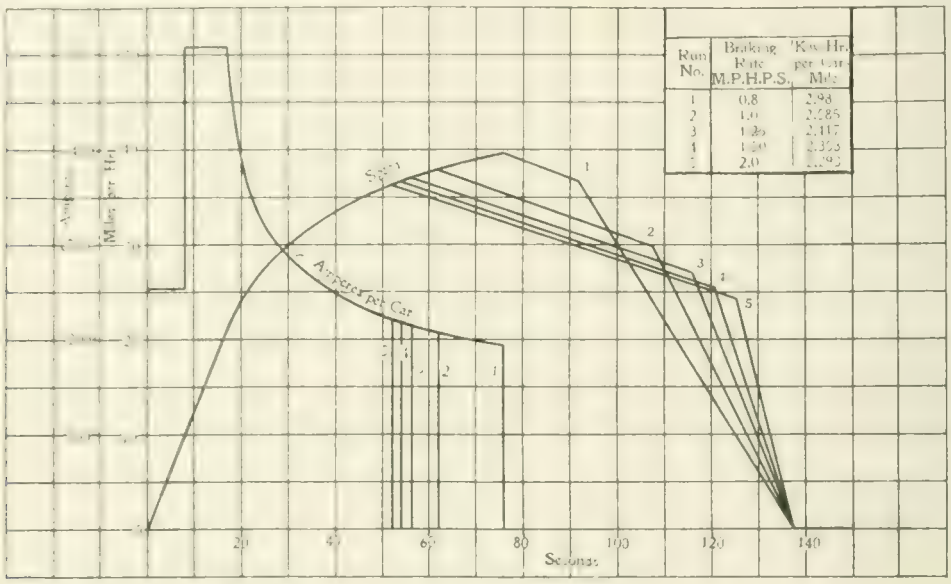


FIG. 3

concerned, rates of acceleration up to two miles per hr. per sec. are in use without objection. Fig. 3 shows a run of one mile at a schedule speed of 24 miles per hr. with various rates of acceleration. The braking rate is constant at 1.25 miles per hr. per sec. A consideration of this figure shows that by varying the acceleration from 0.75 miles per hr. per sec. to 1.5 miles per hr. per sec., the power consumption may be reduced 29.6 percent. It should be noted in this connection, however, that the maximum current requirements vary from 370 amperes per car with the lowest rate of acceleration to 570 amperes per car with the highest rate of acceleration. Hence substation and line capacity must be considered in many instances.

Coasting—The amount of coasting obtained is a fairly good measure of the difference in power consumption for a given run made under different conditions; because when the amount of coasting is great, it usually means that the acceleration is rapid and that the braking rate is also high. The actual economy obtained by increasing the amount of coasting in any given service is not affected during the coasting period itself, but is the result of more rapid acceleration, with power taken from the line a decreased proportion of the time, and of a higher braking rate with decreased waste of energy in heating the brake shoes and wheels.

Braking—Other things remaining the same, an increase in the braking rate produces a decrease in power consumption because the



Car weight 38 tons. Four 75 hp, 500 volt motors.

FIG. 4

brakes will be applied at a lower speed and consequently there will be less of the stored energy of the car consumed during the braking period. This saving is indicated directly by the decreased time during which it is required to supply power to the car in order to maintain a given schedule. Fig. 4 shows the same run as in Fig. 3 except that a constant accelerating rate is maintained and the braking rate is varied. By varying the braking rate from 0.8 miles per hr. per sec. to 2.0 miles per hr. per sec., the power consumption is reduced 23.1 percent.

A general curve showing the rheostatic losses in an equipment, plotted against the speed at which the rheostats are all cut out of the circuit, the stored energy in a car at any speed, and the power input to the car in bringing it from rest up to any

given speed is given in Fig. 5. The energy to propel a car is utilized in heating the electrical equipment, overcoming rheostatic losses in starting, in heating brake shoes and wheels and in overcoming the friction and windage. The latter item is the useful work and is practically constant for given service irrespective of the method of operation.

By using a motor so designed and geared that the rheostats will all be cut out of circuit at a low speed, the rheostatic losses will be below those obtained when the rheostats are cut out of circuit at a higher speed. With a given equipment, increasing the rate of acceleration produces this result. Higher rates of acceleration permit the car to coast to a lower speed before the brakes are applied and therefore less energy is wasted in heating the brake shoes and wheels. High rates of braking accomplish the same result.

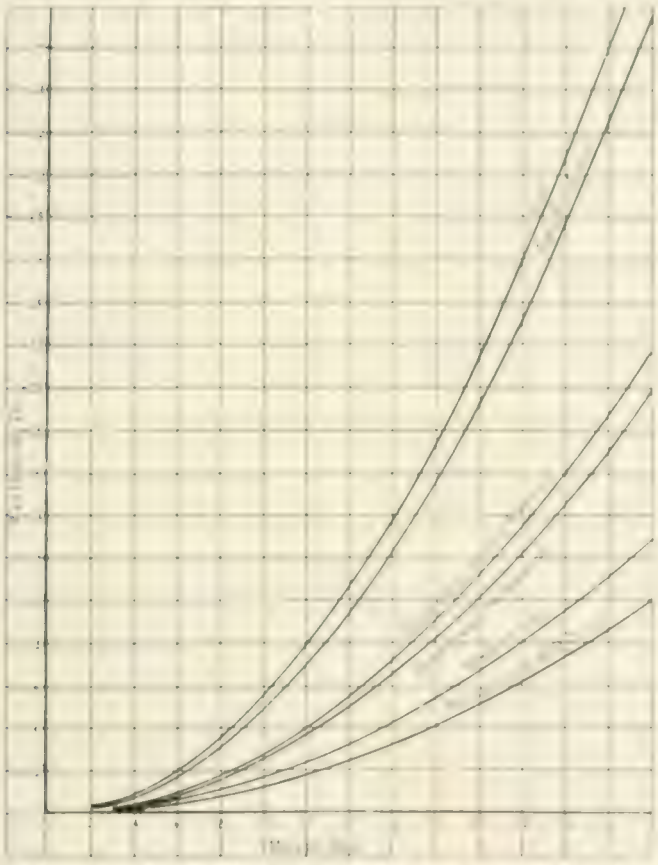


FIG. 5.—ANALYSIS OF POWER CONSUMPTION IN STRAIGHT LINE ACCELERATION

Weight based on 1 ton, motor efficiency at full voltage 85 percent, acceleration 1.7 mi. per hr. per sec., accelerating power, 183 lbs. Control, series-parallel; series parallel with field control.

The curve in Fig. 5 marked "rheostatic losses" shows what may be accomplished by cutting out the rheostats more quickly. The curve marked "stored energy no rotational" gives a measure of the amount of energy wasted in braking from any given speed and shows what may be accomplished by applying the brakes at a lower car speed. This curve is used in preference to the one including the energy of rotation in armatures, gears, wheels and axles since this rotational energy will be about balanced by the train resistance while braking.

FIELD CONTROL

The question that naturally arises is, what are the advantages of field control? The answer is brief, to save power. This is accomplished on the same general principle by which power is saved by the use of slow speed motors and high gear ratios; namely, more efficient acceleration. In Fig. 5, the rheostatic losses with field control are less than for the same speed with ordinary control because field control is used in series in place of the last resistance step. Fig 6 shows the speed and tractive effort curves of a 40 hp field control motor with maximum gear ratio and 33-in. wheels. Fig. 7 shows the characteristics of the corresponding slow speed motor without field control, and Fig. 8, the corresponding light weight motor. From these curves it is seen that the speed of the field control motor on normal field is about the same as that of the slow speed motor without field control, while the speed of the field control motor on full field is very low. The full field is used in accelerating and therefore the rheostatic losses are greatly reduced. The normal speed is used for running and enables the car to at-

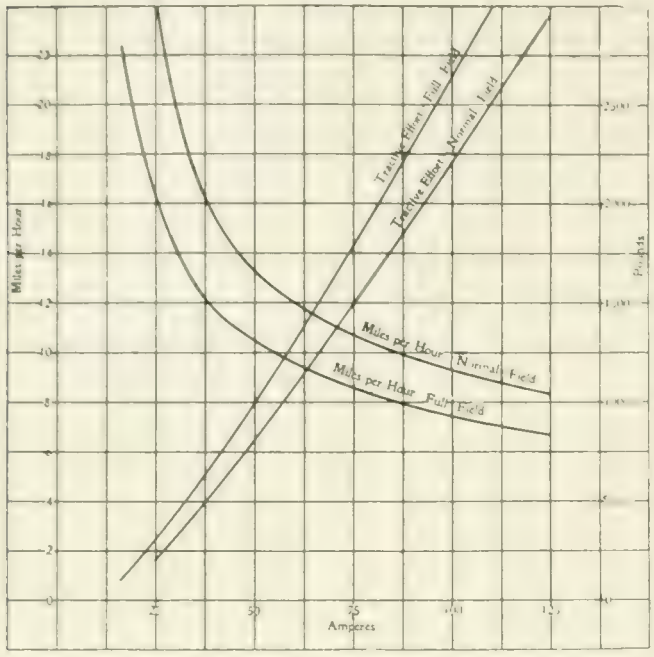


FIG. 6

Field control; 40 hp. 500 volt motor; 5:12 gear ratio; 33 in. wheel.

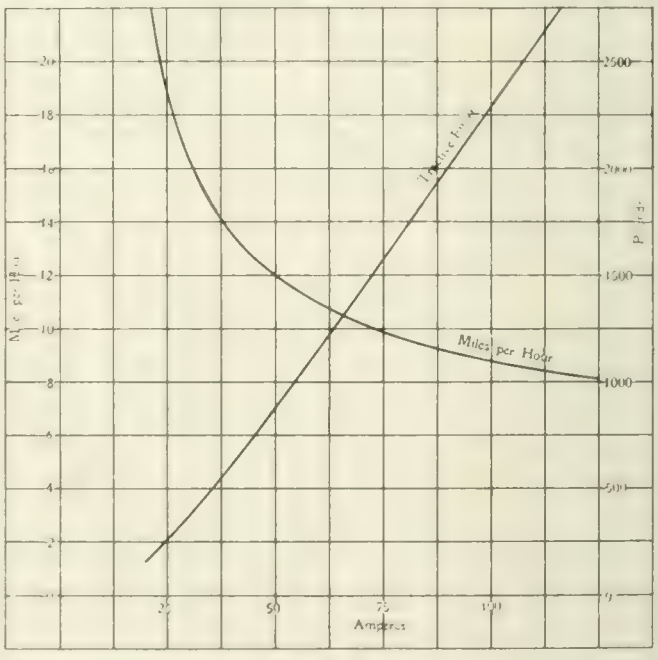


FIG. 7

Standard 40 hp. 500 volt motor, 5.12 gear ratio, 33 in. wheel.

tain the same speed as with the non-field control motor, so that the braking losses are not increased.

The following example will serve to show the saving which may be obtained by field control. Suppose that the tractive effort per motor required to give the necessary acceleration is 1 575 lb. With a non-field control motor this takes 75 amperes and with a field control motor only 68.5 amperes. The rheostatic losses are all cut out at 8.9 miles per hr. with field control motor, but are not cut out until a speed of 9.9 miles per hr. is reached with the non-field control motor. Reference to the general curve Fig. 5 will show that the corresponding rheostatic losses are 1.07 watt-hours per ton with the field control motor and 1.62 watt-hours per ton with the non-field control motor. In other words, the field control motor saves 0.55 watt-hours per ton every time the car starts. If the car weighs 30 tons and makes nine stops and starts per mile, the saving is 0.149 kw-hr. per car-mile.

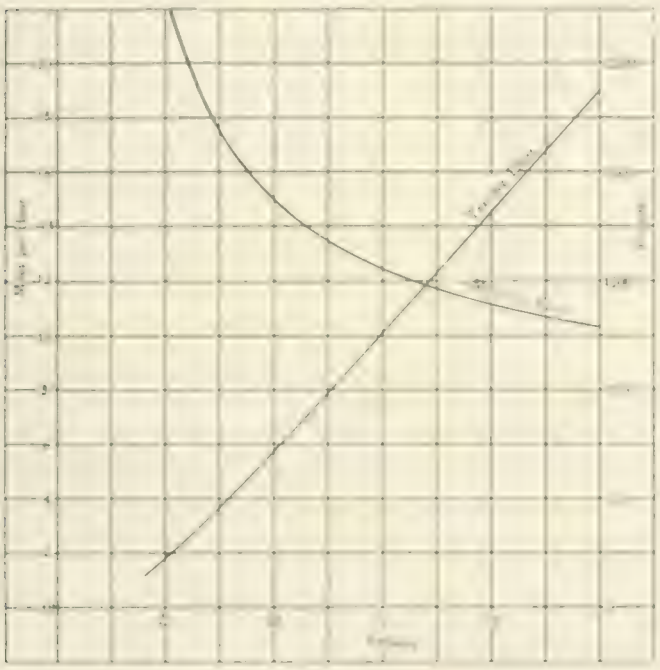


FIG. 8.

Lightweight 40 hp. 500 volt motor, 5.12 gear ratio, 33 in wheel.

Fig. 9 shows the same run as in Figs. 1 and 2 made with the same acceleration as used for the slow-speed motor in Fig. 2. Table I gives the results from Figs. 1, 2 and 9. The power consumed is 3.30 kw-hr. per car-mile or 9.6 percent less than with the slow-speed motor of Fig. 2 and 19.5 percent less than with the high-speed motor of Fig. 1. In this case, the use of a slow-speed motor instead of a high-speed motor reduces the power consumption 10.9 percent while the use of field control makes a further reduction of 9.6 percent and the combination of slow-speed motor and field control produces a saving of 19.5 percent.

For a combined city and suburban service, similar results are obtained. The application of field control to the example of this class previously considered, shows that the field control motor will make the trip with 35.76 kw-hr. and therefore will save 10.4 per-

cent of the power used by the slow-speed motor and 150 percent of that required by the high-speed motor.

For interurban service, field control produces more economical

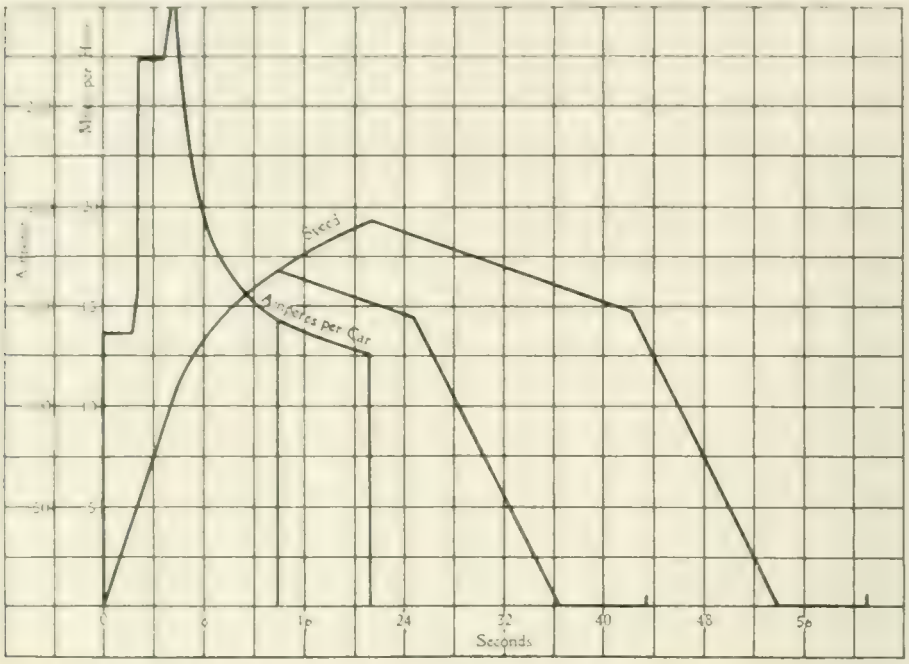


FIG. 9

running over the slow-speed city sections, permits the use of a gear ratio which is economical for local service and with the same gearing gives a higher limited speed than could be obtained with the

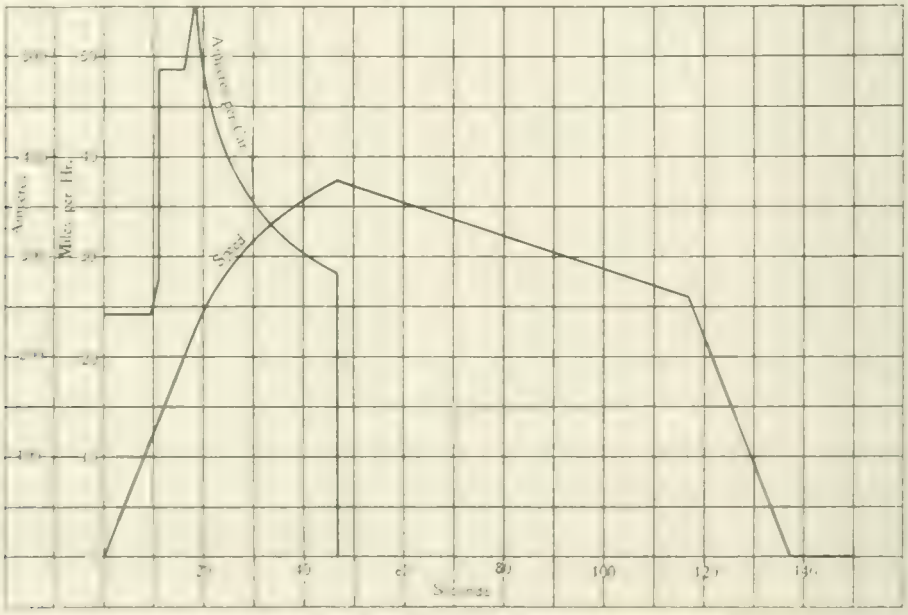


FIG. 10

same size non-field control motor geared for the local schedule. This tends not only toward economy in local service, but also towards reducing the motor capacity required for the operation of

frequent-stop local service and high-speed limited service with the same gear ratio.

A 75-hp field control motor geared for local service, as heretofore described, and operating as shown in Fig. 10, will maintain a limited schedule speed of 38.4 miles per hr. which is the same as that possible with the next size larger non-field control motor. At the same time the reduction in power consumption is 15.9 per cent for local service and 11.7 percent for limited service. The power consumption in limited service is somewhat more than with the ordinary 75 hp motor on account of the faster schedule speed

TABLE I. COMPARISON OF RESULTS OBTAINED WITH MOTORS OF DIFFERENT TYPES

Length of run—miles	.87			1.056		
Time of run—sec.	43.4			61		
Stops per mile	9			7		
Length of stop—sec.	7			7		
Schedule speed—miles per hr.	9.7			11.8		
Braking rate—miles per hr. per sec.	1.25			1.25		
Motor equipment	4-40-hp.			4-40-hp.		
Gear ratio—33/80 wheels	3.12			3.12		

Motor type	Light car	Standard car	Field control	Light car	Standard car	Field control
Motor cur. per mot. at 40 hp. at 500 volts	6.65	5.26	5.5	6.65	5.21	5.1
Amperes at full load of motors	71	71	73	71	71	73
Car weight—equipped and packed—lbs.	29	30	30	29	30	30
Accel. amperes per motor	71	71	65.5	71	73	65.5
Accel. rate—miles per hr. per sec.	1.5	1.55	1.55	1.5	1.55	1.55
Speed when rheostats are all out	12.4	9.9	8.9	12.4	9.9	8.9
Coasting time—sec.	7.5	7.5	10.5	19.5	13.3	16.5
Speed at time brakes are applied—miles per hr.	16.7	15	13.5	15.3	16	14.7
Watt-hr. per passenger	145	125	118	95.4	96.7	86.7
R.m.s. amperes per motor	38.3	33.3	32.4	33.9	30.4	29.7
Temp. rise in service from air 70 degrees C.	65	47	45	59	42	40
Kw-hrs. per car-mile	4.21	3.75	3.39	3.55	3.00	2.67

maintained with the field control motor. The comparative results are shown in Table II.

Table III shows the results of tests on the Frankstown Avenue line of the Pittsburgh Railways Company. The cars and equipments in this case were identical except for gear ratio.

Test *A* was made with a slow-speed gearing, while test *B* was made with a higher-speed gearing. A comparison of the service conditions shows that they were approximately the same the slightly higher schedule speed in test *B* being balanced by the somewhat fewer stops and slow-downs, shorter duration of stop and decreased average passenger load. The railway company had in service a number of cars equipped as for test *B*.

The car geared as for test *A* was operated in regular service for a considerable period of time prior to the tests and proved itself capable of maintaining the schedule equally as well as the car geared for higher speed. It will be noted that not only did the

TABLE II SHOWING POWER CONSUMPTION PER CAR MILE

Length of run—miles	1	1	1	6	6	6
Time of run—seconds	150	150	150	611.8	563	563
Length of stops—seconds	12.5	12.5	12.5	60	60	60
Schedule speed—m. per hr.	24	24	24	35.3	38.4	38.4
Accel. rate—mi. per hr. per sec.	1.25	1.25	1.25	1.25	1.25	1.25
Braking rate—mi. per hr. per sec.	1.25	1.25	1.25	1.25	1.25	1.25
Motor equipment	4-75 hp	4-75 hp	4-90 hp	4-75 hp	4-75 hp	4-90 hp
Motor type	Standard	Field control	Standard	Standard	Field control	Standard
Amperes at full load of motor	150	120	156	120	130	156
Car weight—empty and loaded—tons	28	28	29.5	28	38	39.5
Accel. amperes per motor	147	150	177.5	127	142	177.5
Speed at which rheostats are all out—mi. per hr.	21.3	12	8.2	21.3	20.3	28.2
Coasting time—seconds	60	70	77.5	67.8	86.2	86.7
Speed when brakes applied	17.1	26	23.7	20	30	30
kw.-h. per car-mile	3.4	2.7	2.70	2.025	2.11	2.39
Watt-hrs. per ton-mile	60.7	48.4	48.4	35.4	55.5	60.5
Temp. rise in service from air 25 degrees C	58	60	70	50	58	60

tests show that the low-speed gearing effected a saving of 13.8 percent in the power consumption, but they also showed that, whereas the equipments with the high-speed gearing were operating with

TABLE III TESTS ON FRANKSTOWN AVE. LINE OF PITTSBURGH RAILWAYS COMPANY

Showing effect of gear ratio on power consumption and motor heating

Items	A	B
Weight of [illegible]	19,000	19,000
Weight of [illegible]	23,000	23,000
Motors	4-50 hp	4-50 hp
Gear ratio—[illegible]	4.6	7.67
Schedule speed—miles per hr.	9.15	9.50
Stops per mile	8.7	8.63
Stops—seconds per mile	1.94	1.37
Average variation of volts per car	6.5	6.2
Average [illegible]	37	30
Average voltage	480	480
Watt-hours per car-mile	127	159
Average temperature rise on armatures corrected to 25 degrees C. air temperature	68.8	87.8

A saving [illegible] of 13.8 percent of the power used by B; reason: correct gearing. Day's service consisted in each case of two round trips with trailer, then three round trips without trailer, followed by two round trips with trailer.

dangerous temperature rise, with the low-speed gearing the heating of the motors was just within safe limits. All equipments of these same motors installed since these tests were made, have been provided with the slow-speed gears.

Table IV shows the result of a series of tests made on the cars of the Metropolitan Street Railway Company of New York. It will be seen from this table by comparing tests 1 and 2 that the use of a slower speed armature and greater gear reduction effected a power saving of 7 percent. In test 3, throughout the congested district the equipments were operated in series only and then operated in series and parallel on the remainder of the runs. In spite of the fact that this test shows nearly 23 percent more stops than test 2, the power consumption was decreased 5.5 percent due to the use of field control.

In test 4 the number of stops and other service conditions are practically the same as in tests 1 and 2 but the motors were operated making full use of the field control in series and parallel over the entire line. This test showed 7 percent less power consump-

TABLE IV—TESTS SHOWING EFFECT OF GEAR RATIO AND FIELD CONTROL ON POWER CONSUMPTION

Test No.	Weight of trailer, car and load	R.P.M. at 10 m.p.h.	Gear ratio	Stops per mile	Stop per cent of total	Average length of stop sec.	Schedule speed miles per hr.	Watt hr. per ton mile
1	40,734	600	4.6	6.975	[illegible]	[illegible]	7.176	167.36
2	40,734	600	4.6	6.775	[illegible]	[illegible]	7.264	154.00
3	40,734	445	5.15	8.333	[illegible]	[illegible]	7.147	145.50
4	40,734	445	5.15	6.551	[illegible]	[illegible]	7.400	143.41

1—Standard 60 hp motor. 2—Standard 40 hp motor. Saves 7 percent of power used by 1. 3—Same as 2 except 60 hp motor. 4—Field control 40 hp motor. Saves 12 percent of power used by 3. Saves 5.5 percent of power used by 2. 4—Field control 40 hp motor. Saves 12 percent of power used by 3 (same schedule). Saves 7 percent of power used by 2 (same schedule).

tion than test 3 with its greater number of stops and 12 percent saving in power in comparison with test 2, where the service conditions were practically the same. Substantially all of this saving was due to the use of the field control motor in test 4 as against the non-field control motor in test 2. In this connection, it should be noted that while the 60 hp motors of test 1 showed an average temperature rise of about 48 deg. C. corrected to air at 25 degrees, the 40 hp motors in test 4 showed only 58 degrees rise, which is still a perfectly safe operating condition.

Summing up the results of calculations and tests as previously described in detail, it is found that proper gearing and armature speed, correct operation and field control are essential to the most economical operation of railway service and the indications are that from 10 to 30 percent of the power now consumed in specific cases may be saved by a careful study of the operating conditions and the intelligent application of these principles.

THE GROWTH AND DEVELOPMENT OF THE MODERN RAILWAY MOTOR

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Railway Department, Westinghouse Electric & Mfg. Company

IN the development of the modren railway motor, operators and manufacturers have joined hands, so to speak, in working out the class of apparatus best suited to meet conditions encountered. This is natural, in view of their mutual desire for reliability in service and a minimum of maintainance cost on railway apparatus.

While the satisfactory operation now being obtained from railway motors is commonly credited to the commutating pole construction, this is only partially true. The mechanical construction of railway motors is at least as important as the electrical, and the reliability of modern motors is largely dependent upon radical improvements in mechanical design introduced about 1904.

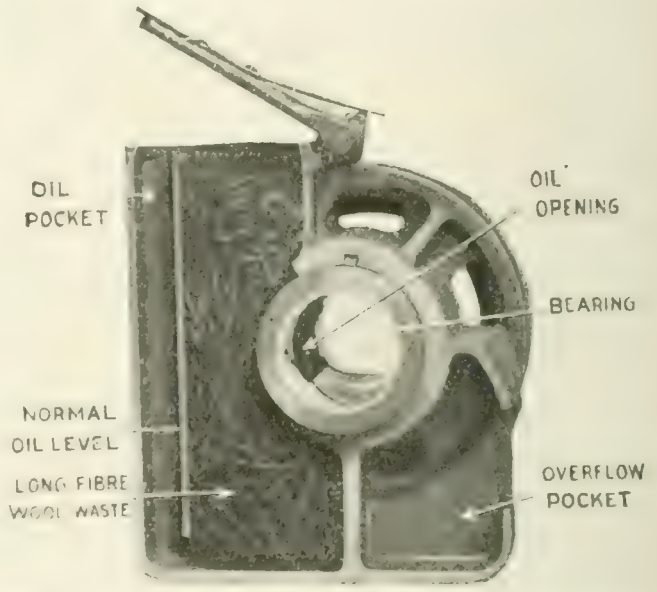


FIG. 1 CROSS-SECTION OF IMPROVED ARMATURE AND BEARING

LUBRICATION

Efficient lubrication, important in any machine, is vitally so with railway motors, since the working conditions are most exacting. In the earlier designs trouble was experienced due to the gravity method then used. This consisted of a grease receptacle mounted directly over the bearings, which allowed dirt, grit and other impurities in the lubricant to be carried to the bearing surface. This materially shortened the life of the bearings.

To secure a system of efficient lubrication, the scheme of using oily waste was incorporated in the construction of certain motors about 1905. In this construction the bearings are pressed and keyed in a housing consisting of three compartments: an oil pocket, a waste pocket and an overflow pocket. The waste pocket holds long wooden waste against the low pressure side of the arma-

ture shaft through an opening in the bearing. Oil is poured into the oil pocket and through a bottom connection reaches the waste. The oil then filters up to the bearing by capillary attraction, leaving all dirt and grit at the bottom and beneath the waste. The normal oil level is just below the opening in the bearings and, therefore, when the car is not in motion no oil is being consumed.

The amount of oil in the pocket can be gauged at any time, and many companies have adopted the practice of using a marker to gauge the depth of the oil. By this method it can be determined how much, if any, oil is required. With oily waste lubrication it has been found practicable to replenish the oil supply for armature bearings once every thirty days, and records have been established of 250 000 miles for the life of armature bearings.

The increased reliability, due to the elimination of service failures; and the decreased cost of maintenance due to lower oil consumption, longer periods of inspection, increased life of bearings and elimination of expensive repairs to armature and fields, have resulted in this type of lubrication being adopted on all modern railway motors. Essentially the same scheme is used for lubricating of axle bearings on both split and box frame motors.



FIG. 2—CROSS-SECTION OF AXLE CAP FOR BOX FRAME MOTOR

Cut to show oily waste system of lubrication.

ARMATURE CONSTRUCTION

When the slotted laminated cores first came into use the laminations were pressed and keyed directly on the armature shaft. It was found, however, when a shaft became bent or broken and had to be replaced, that considerable difficulty was encountered in keeping the commutator and core from shifting and thus damaging the windings. In addition, the key holding the laminations in place were subjected to severe service stresses imparted directly from the armature shaft. This was due in part to rough track, fairly high speeds, and reversals, which tended to cause shifting of the laminations.

With a view of overcoming the difficulties encountered, the spider armature construction was adopted. The laminated core built of soft steel punchings is pressed on a steel or malleable iron spider. These punchings are held between the core head at the rear, which is a part of the spider, and the end plate at the front

end, which is secured by a ring nut working on a threaded portion of the spider. The commutator is pressed on and then the shaft is pressed into the spider.

This type of construction appears to fulfill present-day requirements in that a bent or damaged shaft may be pressed off without disturbing the armature windings. In addition the spider acts as a strong sleeve, reinforcing the shaft and forming a very solid and compact construction, decreasing the probability of bent or damaged shafts. Shocks encountered by the armature shaft are not transmitted directly to the laminations, as in the case of the earlier construction, and the effect is but secondary since the spider tends to absorb these shocks as encountered.



FIG. 3—AN ARMATURE SPIDER

BRUSHES AND BRUSH HOLDERS

For almost a decade, consideration has been given to the value of carefully regulating brush pressure to suit the widely varying conditions of service. For slow speed city schedules over good track, a pressure of four to five pounds works out satisfactorily. If, however, it is attempted to use such pressures in severe high speed service—which ordinarily require seven or eight pounds—sparking and flashing occur. On the other hand, too heavy a pressure will cause rapid wear of commutator and carbons, and over-heating due to frictional resistance.

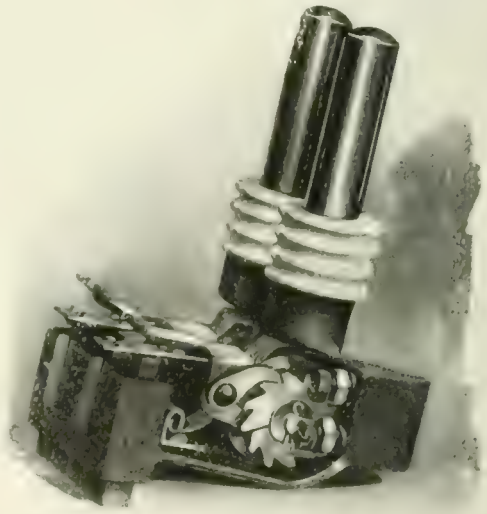


FIG. 4—BRUSH HOLDER
Cut out to show pawl and ratchet attachment.

Brush holders which permit of adjustment of the pressure on carbons have come into general usage. Each brush is provided with a flat phosphor bronze coil spring, with pawl and ratchet attachment to secure the brush pressure that may be required.

A flat copper braid shunt is connected to the hammer in direct contact with the carbon, which provides a path of low resistance between the holder casting and the brush. This tends to eliminate wear and burning of the brush holder guides and carbons.

The brush holders are firmly clamped to seats on the motor frame, securing positive alignment of brushes with respect to the commutator and each other. This is a distinct improvement over the earlier method of mounting the brush holders on wood or fiber blocks. This is particularly important since the advent of commutating pole construction for, although the neutral point or the position of commutation is more sharply defined, the limits are narrower and greater care must be taken to secure proper alignment.

FIELD POLES AND COILS

Solid pole pieces, cast with motor frame, were common to the earlier railway motors. This construction has been superseded by



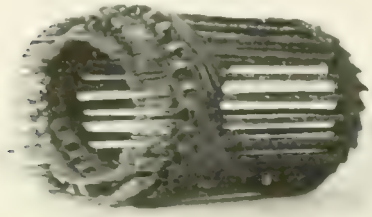
FIG. 3. STRAP WOUND FIELD COIL, CUSHION SPRING, SHIELD AND MAIN POLE PIECE

removable pole pieces. Soft steel punchings, riveted together between malleable iron end frames, are now used for cores of the main pole pieces. This construction permits the use of higher flux densities, due to better grade of material used, gives decreased eddy current losses and increased accuracy in manufacture. Along the same line of endeavor strap wound field coils have superseded wire wound coils on account of greater space economy and ability to withstand heavy pressures without injury to the insulation. This obtains since the pressure is distributed over a large area instead of being applied along the center of the wire, as in the case of wire wound coils. Heavy springs beneath the field coils to prevent vibration are therefore permissible. To protect the coils from mechanical injury, metal shields are extended over the face and inside the coil.

Field coils are impregnated with the best heat and moisture resisting compounds known. With strap wound field coils less-

compound is needed than with wire wound coils. Heat radiation is, therefore, greatly improved with strap wound coils by avoiding spaces filled with a substance which is a comparatively poor heat conductor.

ARMATURE COILS



6—SET OF STRAP WOUND ARMATURE COILS

Strap wound armature coils have been adopted on motors of 60 horsepower capacity and above. Space economy of armature coils is even more important than in the case of field coils, and since approximately ten percent greater section of copper can be obtained for a given size of slot the desirability of using strap wound coils is apparent. The "two-turn" strap wound coils are formed in the exact contour to be assumed in the armature slots, and hence bending, twisting or pounding is unnecessary in applying.

The armature slots have "U" shaped piece of insulation, set into laminations at the ends of each slot, reinforcing the coil insulation where it is most needed. Short circuited and grounded coils at slot ends, quite prevalent before the introduction of this "U"-piece insulation, have been eliminated.



FIG. 7—SINGLE COIL, TWO TURN STRAP WOUND COIL

After some months of operation, carbon and copper dust tends to filter through the windings of railway motors, settling to a large extent at the rear of the commutator. Such accumulations tend to bridge over the mica segments and short-circuit adjacent commutatro bars. If the surface becomes greasy or oily this tendency is greatly increased. To prevent such a condition, commutators of modern railway motors have the mica segments extended about 1/8 in. beyond the copper bars at the rear, which renders impossible the bridging over and short circuiting of the bars from this source.

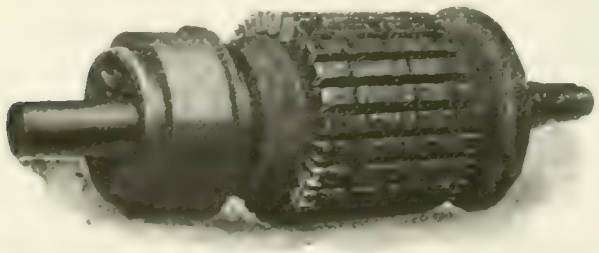


FIG. 8—COMMUTATOR AND LAMINATION OR SPIDER

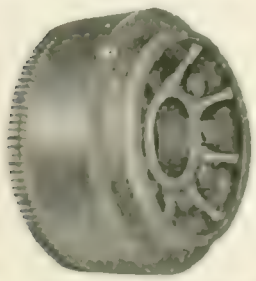
V shaped piece of insulation are fitted in rear slot ends

Whenever a motor flashes at the commutator there is always the possibility of the arc injuring the armature coils, and as a source of protection asbestos hooding is now used on the front of the armature.

COMMUTATORS

The commutators in the earlier railway motors were of the ring nut construction. The copper bars and mica segments were held between the front and rear steel V-ring. With this type of construction certain disadvantages were present, in that the commutator bars could be made tight only with difficulty, and further, it was difficult to back out the ring nut, due to the accumulation of dirt, grime and rust.

To obviate these difficulties the bolted type construction was introduced, in which commutators are mounted on a separate steel bushing, the steel V-rings, clamped together by tap bolts, holding the commutator bars in place. A "T" socket wrench may be conveniently applied and sufficient stress exerted to secure the segments positively, thus preventing loose or high bars. When it becomes necessary to replace the bars the tap bolts may easily be backed off.



The under-cutting of commutator mica has proven so successful in eliminating commutation troubles that it is used on armatures from the size of the giant Pennsylvania locomotive motors down to small compressor motors. The troubles formerly encountered were due largely to the difficulty in securing mica and copper with identical wearing qualities. Commutator mica is ordinarily under-cut to a depth of 3/64 inch, and the saws or tools used are from 0.002 to 0.003 inch wider than the mica segments. The use of high grade brushes in connection with slotted commutators has greatly simplified the commutation problem.

The bands used to insulate the exposed surface of the front steel V-ring from the commutator copper are given a high polish to prevent the accumulation of non-insulating dust and to present a surface which may be readily cleaned by wiping.

GEAR CASES

Safety clamps are now used on gear cases to prevent the lower half from dropping should the nut work off the connecting bolt.

This nut, however, is held by a lock washer, and in addition a cotter is placed through the bolt. It would be necessary for both the cotter and the washer to loosen before the nut could work off. The clamp has two ears on the upper side turned up, through which the cotter is placed. These ears prevent the bolt head from turning and the cotter prevents the bolt from jolting out, should the nut work off. With this construction it is practically impossible to drop a gear case.

Two-point suspension of gear cases has become very popular, since rigid support is assured, lateral vibration and strains reduced, wear on bolt holes minimized, and temperature strains cause no difficulty.

MOTOR FRAMES

It has been generally agreed among railway men that for motors of above 75 horse-power capacity the box frame is the more desirable, since no clamping bolts are required, less mounting space on the truck is necessary and the weight is less than the corresponding split frame motor.

For 75 horse-power and smaller motors it is still true that greater mechanical strength and the absence of clamping bolts are in favor of the box frame motor, but properly constructed split frame motors have what may be termed "compensating advantages" in that the armature, armature housings, armature bearings and field coils may be removed from the motor for inspection or repairs without jacking up the car and running out the truck. It is possible to open up the motor so as to expose the parts and make light repairs. These features of a split frame motor are of particular advantage to city and interurban railways of moderate size, or to comparatively large properties where cars are stationed at a number of barns.

During the past seven or eight years considerable thought and attention has been given to the design and construction of split frame motors. As a result the modern split frame motor possesses mechanical rigidity of a very high degree, due first to the fact that the armature housings are held in place by two radial bolts, which assume the weights and stresses imposed by the armature, and second, four large bolts are used whose only function is to hold the two halves of the frame together. The hinge lugs at the rear of the motor are made distinct from any clamping arrangement and this too has added very materially in securing

proper rigidity. The armature bearings are held in bushed caps between the frame bolts and are fastened with machined flanges which practically dowel two halves of the frame together when the frame bolts are tightened.

Box frames for the smaller sizes have been adopted by a number of large properties on account of the greater mechanical strength. In addition, where proper shop facilities are available, such as traveling cranes and car hoists, a car can be raised, truck removed and armature or complete motor changed in about the

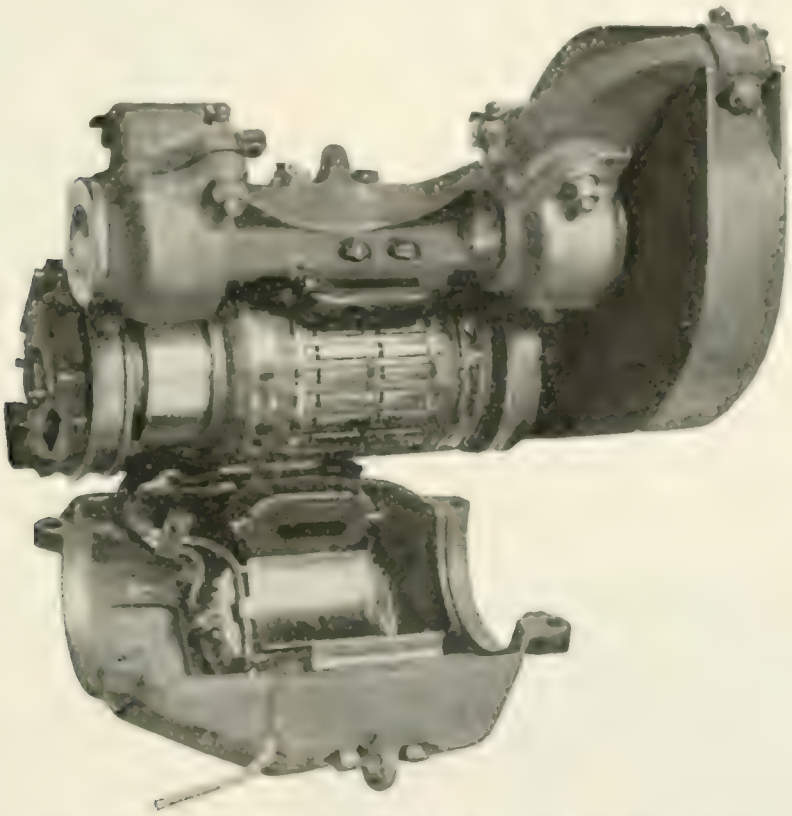


FIG. 10.—MOTOR WITH LOWER HALF OF FRAME LOWERED.

same, or less time, than is required to repair a split frame motor. In larger shops, handling many motors, more efficient work can be done by placing the motors on the floor where wrenches may be applied to the best advantage.

LIGHT WEIGHT MOTORS

During the past three years, considerable thought has been given to reducing equipment weights and the securing of increased economies, the object being decreased power consumption. Modern railway motors are now as light as is consistent with the me-

chanical strength required for safety and reliability in operation.

The study of the electrical characteristics in selecting a motor for a given service, has proven even more profitable in decreasing power consumption than has the reduction in motor weights. It has been found that for ordinary city service, or, in fact, any service where stops are frequent, there is rarely any necessity for a car speed greater than that which can be obtained with a motor of the lowest r.p.m. that is now generally used, when arranged with greatest gear reduction possible. A motor built for a higher r.p.m. requires a greater current to produce a given acceleration. The current inputs will be proportional to the speeds of the motors. The saving in power consumption is due to the decreased losses during acceleration.

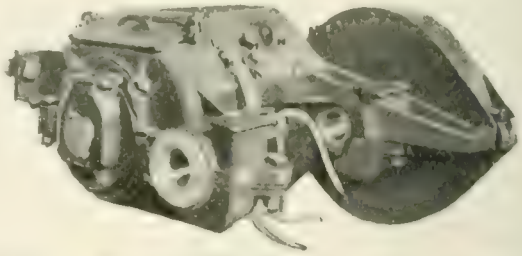


FIG. 11—LIGHT WEIGHT SPLIT FRAME MOTOR

32 hp, 500 volts; 38 hp, 600 volts; weight 1800 lbs.

It is not so much a question of motor efficiencies but of equipment efficiencies involving the rheostatic loss, or, in other words, the I^2R loss of the grid resistance. In many of our larger cities, the railway companies have found it profitable to eliminate high speed gear ratios and the substitution of greater gear reduction has proven very satisfactory in saving power. In many cases, the number of stops precluded any possibility of making use of the high speed characteristic.

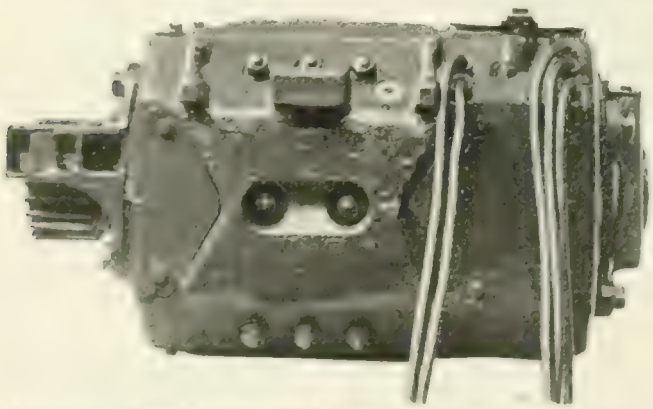


FIG. 12—600-1200 VOLT BOX FRAME FIELD CONTROL MOTOR

Showing suspension, nose and safety lugs.

FIELD CONTROL

Field control motors have been introduced to effect further saving in power consumption. The number of active field turns on these motors can be varied, permitting efficient operation at low speeds and the attainment of relatively high speeds when desired. The saving in power consumption accrues from the decreased rheostatic losses in starting and the reduction of energy losses in braking since the higher

speeds will usually allow a greater time for coasting. The first extensive installment of field control that proved successful was on the locomotives of the New York, New Haven & Hartford Railroad Company during 1907. When operating in the direct-current zone out of New York, their speed is regulated by field control. On account of the great inactive effort required in starting, and the high speeds desired, the locomotives for the Manhattan Division of the Pennsylvania Railroad use field control. Where combined city and suburban running is encountered, or on the interurban roads where cars must operate in both limited and local service, the application of field control is ideal. The motor operating on full field in city service consumes only a minimum of power, while the advantages of higher speeds are gained from operation on normal fields in the suburban sections. In the same manner, interurban cars can run efficiently in local service on full field and when in limited service, use the normal field to obtain the necessary high speed. Before the advent of field control, it was necessary to either select a gear ratio to give the highest speed required, or a compromise gear ratio. The first method resulted in excessive power consumption on the lower speed runs, and while the second method caused this consumption to be decreased, it was accomplished through the sacrifice of the higher speeds desired.



FIG. 13. MOTOR ARMATURE FOR FOUR-POLE WESTINGHOUSE MOTOR

FORCED VENTILATION

Forced ventilation has long been used to secure increased, continuous capacity of motors. The locomotives on the New York,

New Haven & Hartford Railroad in operation for the past five years, use such a system. In addition, locomotives of the Spokane & Inland Empire, St. Clair Tunnel, and New York, Westchester & Boston Railway, and motor cars of the New Haven road, the Long Island Railroad and the Pennsylvania Railroad, have motors utilizing the forced draft feature. Auxiliary blower motors are used, ventilating the windings through openings in the motor frames. The air is taken from the inside of the cab or from a point of sufficient height above the roadbed to preclude the possibility of dirt, sand, brake-shoe dust, and snow getting into the motors. To assist in the artificial ventilation, fans are placed at the rear end of armatures and vents placed in spiders and beneath commutators. This method of fan ventilation has since been applied to smaller motors for city service, but the tendency for motors on street cars to accumulate dirt has prevented wide application in this service. For the past four years, street railway motors have been designed and constructed to gain inherently good ventilation. This is obtained by longitudinal vents in the spider which connect with radial ducts in the laminations. Air currents are set up through the spider and laminations facilitating the radiation of heat from the core and windings. The independent cell insulation surrounding the coils eliminates the possibility of dust or other substances injuring the coil insulation.

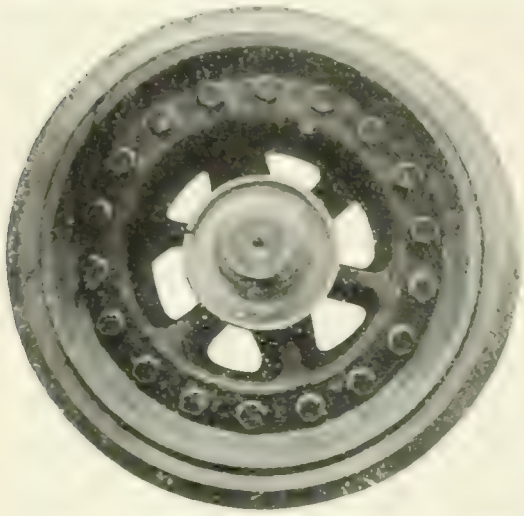


FIG. 14 END VIEW OF ARMATURE
Showing vents through spider and beneath commutator.

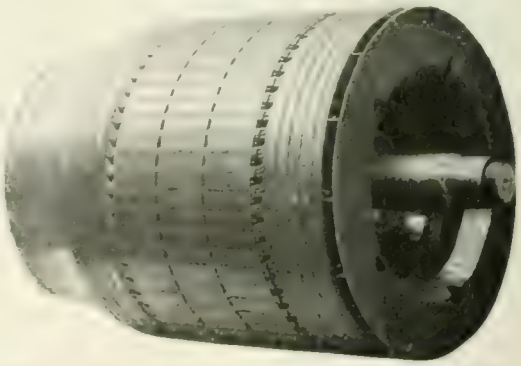


FIG. 15 SINGLE PHASE ARMATURE, SHOWING FAN CONSTRUCTION

With the increasing congestion in cities, the traffic problem becomes harder to solve, and special means must be adopted to care for the situation. Radical changes in car designs are being made in our larger cities to meet the particular requirements.

Trucks, brakes, control and motors must handle the transportation problem involved and, in addition, fit in with the physical limitations of such design. The latest motor designed to meet such conditions is that first used on the Pittsburgh Railways. This motor was designed for use in connection with an abnormally low car body and for mounting on a truck with 24 inch wheels.



FIG. 16—END VIEW OF SPIDER

With the increase in efficiency along other lines, there have come into general usage, materials of the highest grade and manufacturing processes that a few years ago were unknown to the art. Spiders and shafts of modern railway motors are ground to secure exact fit; armature cores are filed to render all surfaces smooth and corners rounded; and commutator slots champfered to eliminate sharp edges.

With the increased care and thought in manufacture and the use of the highest grade of materials, there is naturally an accompanying increased cost of production. It is unquestionable, however, that the increased reliability in operation and reduction of maintenance that must result, will render the railway industry more stable than ever before.

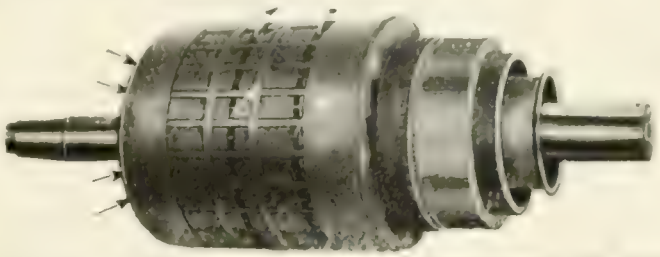


FIG. 17—ARMATURE SHOWING DIRECTION OF AIR CURRENTS

SERVICE REQUIRED OF SWITCHING LOCOMOTIVES IN INDUSTRIAL PLANTS

D. C. HERSHBERGER

THE service conditions for switching work in the yards of large factories are not generally known, except approximately. This is probably due to the character of the work, which makes it difficult to obtain accurate information without careful investigation. Switching work around industrial plants is in many respects different from that performed in the yards of a large railroad. As a rule, the equipment is lighter; runs are shorter but more frequent, and the trailing load less.

In order to determine the actual service conditions in their own yards a series of tests were recently conducted by the Westinghouse Electric & Mfg. Company, at their East Pittsburgh works, on one of their switching engines. The engine used for this test has a two-wheel leading truck and three driving axles. The weight of the engine is 52.7 tons, of which 46. tons are on the drivers. This locomotive is in service 20 hours per day, six days per week. The remaining four hours per day are utilized in coaling, oiling, cleaning, etc. The locomotive is out of service only from Saturday nights to Sunday nights, or in other words, 24 hours per week. At this time, light repairs are made, if necessary.

The zone of operation of this locomotive is confined to approximately 3.4 miles of track. The length of track inside of buildings and under crane tracks is approximately one-half mile. The greatest length of straight track in the above zone is approximately one-half mile. The greatest single length of curved track is approximately one-fourth mile. The track includes curves ranging from 1 to 20 degrees; the shortest curve has a radius of 150 feet. On account of the large number of switches, and the necessary layout of the yards, the length of the curved track is necessarily large, being approximately 40 percent of the trackage. The grades do not exceed one percent, except at tracks leading from loading pits where the grades are approximately two percent.

The tests taken extended over a period equivalent to three ten hour days of daytime operation. In connection with these tests the observers noted for each run:—the instant of starting,

closing of throttle, application of brakes, stopping, length of run in feet, number of cars, and the estimated net weight of each car. The time of starting, closing of throttle, etc., was read in seconds. The length of run was obtained for the first three half-days by means of a counter arranged to register the revolutions of the pony wheels, from which the length of each run was figured. For the last three half-days, the length of run was taken from station markings put throughout the yards for the test.

The trailing load was approximated by averaging the weights of a large number of empty cars of each class and adding to these weights the net weights carried by the respective cars, these being approximated from detail notes taken by the observer. The net weight of sealed cars was obtained by averaging the net weights

TABLE I.—SWITCHING SERVICE PERFORMED IN EACH HALF-DAY OF TEST, AND TOTAL SERVICE FOR THREE DAYS.

	6 to 7 P. M.	7 to 8 A. M.	8 to 9 P. M.	9 to 10 P. M.	10 to 11 A. M.	11 to 12 P. M.	6 to 12 Days Total
No. of Runs with Trailing Load	217	208	267	227	269	237	1445
No. of Runs—Light Engine	40	47	56	60	43	41	287
Total Runs	257	255	323	287	312	278	1732
Power On—with Trailing Load	6171	6541	7965	6457	6579	6789	40502
" " Light Engine	914	978	1472	845	784	997	5990
Coasting " Trailing Load	28	104	345	56	1156	648	3437
" " Light Engine	88	128	47	47	176	97	583
Braking " Trailing Load	1307	1871	1972	1366	2140	1230	10886
" " Light Engine	172	200	312	227	229	170	1310
Run, Length in Ft., with Trailing Load	48218	49257	63172	52925	64540	50415	328527
" " Light Engine	5425	6340	14760	5861	6360	11060	49806
Miles with Trailing Load	9.14	10.03	10.58	10.2	12.23	11.47	64.29
" " Light Engine	2.54	2.93	2.8	1.63	1.81	2.47	14.17
Total Mileage	11.68	12.96	13.38	11.83	14.04	13.94	78.27
Trailing Load—Tons	38865	43525	51734	38540	59027	83005	314771
Ton Miles—Trailing Load only	1807	1768	2004	1804	1821	2506	7668
No. of Cars Moved	1340	1242	1520	1143	1021	950	7146
Car Miles	11	10	13	11	12	13	70

of a large number of sealed cars. The results given in Table I. show the total service for each half-day, and also a three-day total. It should be noted that the term "trailing load" refers to the load hauled back of the locomotive. The service for the various half-days of this test was comparatively uniform with possibly one or two exceptions; one of these is in the coasting time with trailing load. No reason can be assigned for this, except the variation in operation by the train crew. Where the number of runs for each half-day is low, they are usually accounted for by increased tonnage or mileage. In Table II are given the average figures covering service per ten-hour day and also the values for a single average run.

Probably the most remarkable feature of this service is the

exceptionally large number of runs made. Exclusive of occasional short delays, the number of runs average over one per minute. It is a common occurrence to make two movements per minute, and very frequently three movements per minute are made. These runs, however, are usually 100 feet or less in length, and the trailing loads not extremely heavy. The number of light engine runs is comparatively small, averaging 15.8 percent of the total number of runs.

The average time during which power is on is 72.8 percent of the total running time with trailing load, and 72.2 percent for light engine runs. The average time for coasting is 6.7 percent of the total running time for runs with trailing loads, and 7.4 per-

TABLE II.—AVERAGE SWITCHING SERVICE PERFORMED IN A 10-HOUR DAY; ALSO VALUES FOR AN AVERAGE RUN

	Average per 10-hr., day	Average Run with Load	Average Run Light
No. of Runs with Trailing Load	480		
No. " " " Light Engine	90. 4		
Total No. of Runs	570		
Power On, Runs with Trailing Load, Seconds	12640	26. 3	
" " " Light Engine, "	1893		20. 9
Coasting " " Trailing Load "	1157	2.4	
" " " Light Engine, "	194. 5		2.15
Braking " " Trailing Load, "	3558	7. 4	
" " " Light Engine, "	535		5. 9
Length of " in ft., with Trailing Load	113000	235. 3	
" " " " " " Light Engine	24930		276
" " " " " " Trailing Load	21. 4	0.0445	
" " " " " " Light Engine	4.72		0.0522
Total Mileage	26.12		
Trailing Load—Tons	70800	154. 6	
Ton—Miles Trailing Load only	3310	6. 89	
No. of Cars moved	2380	4. 78	
Car—Miles	102. 1	0.213	

cent for light engine runs. When hauling trailing load the number of runs without any coast was 25.2 percent of the total number of runs. With light engine the number of runs without coast was 27.7 percent of the total. The number of runs of both classes without coast was 25.6 percent of the total number of runs per day.

The average time of braking is 20.5 percent of the total running time when hauling trailing loads, and 20.4 percent for light engine runs. The average tons trailing load per run is not a straight average obtained by dividing the total number of tons by the number of runs. This value was obtained by dividing the average number of ton-miles per 10-hour day by the number of movements, and this result, which is the average ton-miles per movement, is divided by the average length of movement in miles. The result is the average trailing load in tons. The same method of

figuring the number of cars per run was also used. The average length of run will probably be more nearly constant than the average trailing load. The reason for this is that about the same cycle of shifting operations is performed each day.

A number of individual runs are given in Table III. These runs were selected to show the maximum and minimum time of

TABLE III—INDIVIDUAL RUNS AS TAKEN FROM TEST SHEET SHOWING MAXIMUM AND MINIMUM TIME OF POWER ON, COASTING, BRAKING, LENGTH OF RUNS, ETC.

Run No.	Time of Power On Seconds	Coasting Time Seconds	Braking Time, Seconds	Length of Run, Feet	Trailing Load Tons	No. of Cars
			Maximum Time of Power On			
1	170	0	10	870	341	14
2	210	30	30	1470	48	11
			Minimum Time of Power On			
3	2	0	2	30	21	2
4	3	0	2	30	21	1
			Maximum Time of Coast			
5	90	70	5	1420	97	7
6	95	45	15	290	574	25
			Maximum Time of Braking			
7	58	0	47	308	317	7
8	45	0	35	200	48	2
			Maximum Trailing Load—Tons			
9	40	6	4	110	860	25
10	20	5	5	160	650	16
11	115	8	27	1 190	697	16
			Minimum Trailing Load—Tons			
12	80	5	5	1030	14	1
13	30	3	3	150	14	1
			Maximum Length of Run			
14	170	5	32	2860	31	1
15	150	0	15	2170	314	8
16	185	8	15	2060	527	11
17	110	8	14	1890	673	17
			Minimum Length of Run			
18	4	0	2	60	21	1

power on, coasting time, braking time, tons trailing load, length of run in feet, and number of cars moved. All runs given in this table are runs with trailing loads. The maximum braking time is shown in run No. 18. Runs Nos. 6 and 9 show the maximum number of cars moved in any one run. Run No. 10 was made inside of a building. In a ten-hour day, approximately 60 runs,

each with an average length of 123 feet and with an average trailing load of 328 tons, are made inside of buildings and under crane tracks. These runs were made in groups of approximately ten each. This service comprises approximately 12 percent of the total number of shifts made. The average number of times the locomotive was reversed was 65 percent of the average total number of runs per day. The figures given in Table III show that the trailing loads, length of run, number of cars moved per run, time of power on, etc., vary greatly.

The accelerating rates also vary over a wide range, being as low as 0.01 mile per hour per second for some runs with heavy trailing load inside of buildings, to 1.5 miles per hour per second with light trailing loads or light engine. The average accelerating rate for runs with average trailing load was 0.326 mile per hour per second. The average adhesion for accelerating with trailing load was approximately 12 percent of weight on drivers. The average accelerating rate for average light engine runs was 0.86 mile per hour per second, corresponding to 10 percent adhesion on drivers.

The braking rates also vary considerably, being from 0.1 to 2 miles per hour per second. The average braking rate with average trailing load was 1.08 miles per hour per second, and for light engine runs 1.6 miles per hour per second. For these braking rates the adhesion was approximately 23 percent for runs with average trailing load, and 7.5 percent for light engine runs.

The average maximum speed attained for runs with average trailing load was approximately 8.5 miles per hour and, without trailing load approximately 10 miles per hour. The maximum speed was sometimes as high as 20 miles per hour with light engine or engine with small trailing load.

The locomotive miles per year amount to approximately 16 000 for double-turn operation, 20 hours per day for six days per week. The average speed, including stops, is 2.5 miles per hour. The total car-miles per year are approximately 61 000.

In conclusion it should be noted that with the track layout as at present, a 60-ton locomotive with 52 tons on the drivers would perform this service more satisfactorily, especially in moving the heavier trains. However, by providing a greater length of storage track, to eliminate such frequent shifting of the same cars and by reducing the weights of the trailing loads, a 52-ton locomotive would still perform this service.

A locomotive in switching service of this kind requires good air-brake equipment, both as to capacity and reliability. The air lines to the train are seldom, if ever, connected; therefore, all braking operation depends upon the locomotive alone. However, with this method of operating, the losses due to air leakage are very low, and the efficiency of the air-brake system is high.

The total weight of a switching locomotive should be on the drivers if possible, thus giving maximum tractive effort for accelerating and braking. This is indicated to a certain degree by the large number of times the wheels are slipped when handling comparatively heavy trailing loads. The shocks due to bumping and coupling cars are very severe, as a rule, especially with short trains. However, with trains having a large number of cars, these shocks are taken up by the spring couplers and are greatly reduced when they reach the locomotive.

As a general rule, the tracks in a manufacturing plant are level, with the exception of pits and trestles for loading and unloading purposes. In such cases the grades are usually somewhat severe. The curves are of short radius and large in number, due to the necessary layout of yards of this kind. Many industrial yards are hampered for trackage. This often necessitates shifting the same cars several times in order to place other cars in the desired positions.

THE MULTIPLE OPERATION OF CARS GEARED FOR DIFFERENT SPEEDS

W. R. STINEMETZ

IN the inauguration of a new road it is sometimes a difficult matter to predetermine the proper schedule and equipment to meet the service demands which may arise. The service as planned may be deficient due to unexpected increase of traffic which necessitates the operation of trains instead of single cars. It may also be necessary to increase the schedule due to competition, or the growth of the district may require additional stops for both the local and limited trains, and the light freight and express business may prove far in excess of that for which provision was made. As, in all probability, the equipments have been furnished to meet the conditions of the demands of traffic which it was reasonable to expect at the inauguration of service, with due allowance for normal growth, the management is confronted with the problem of how to care for these changed conditions without additional equipment.

One phase of this problem, where the equipment has been selected with different gear ratios in order to handle great variation in schedule, is the question of operating these differently geared cars in the same train. While it is generally known that the acceleration will be poor, if automatic control is used, and that the motors will not divide the load equally, the serious overload that may be thrown on some of the motors with this class of operation does not always receive due consideration. In order to study the effects on the motor, when operating a car geared for slow speed coupled to a high speed car, the following conditions are given:—

A road anticipates a demand for a high-speed limited service with single cars, a local service over the entire line, and at certain periods of the day, a heavy local service for 10 or 12 miles on one end, together with a certain amount of light freight and express business from the small villages which it touches. The same size of equipment is selected for all of the cars.

For the limited service eight straight passenger coaches are provided which weigh loaded thirty-two tons each. They are each equipped with four 50 horse-power motors geared to give a schedule speed of 30 miles per hour when making one stop every five miles. These cars can also handle a limited local service of one stop every 1.6 miles at a schedule speed of 25 miles per hour.

Four combination mail and passenger coaches are provided of the same weight and with the same equipment of quadruple 50 horse-power motors but geared to a much lower speed ratio, for the purpose of handling the through local service. This will consist of one stop every two miles at a schedule speed of 21 miles per hour and also the short local rush service mentioned, of 18 miles per hour when hauling a trailer weighing 20 tons loaded.

In addition two freight cars are provided with the same equipment as the combination mail and passenger cars and geared for the same speed. It was planned to use these not only for the freight and express service, but also to couple them with the mail and passengers cars, and so, together with trailer coaches, provide four or five car trains for particularly heavy days.

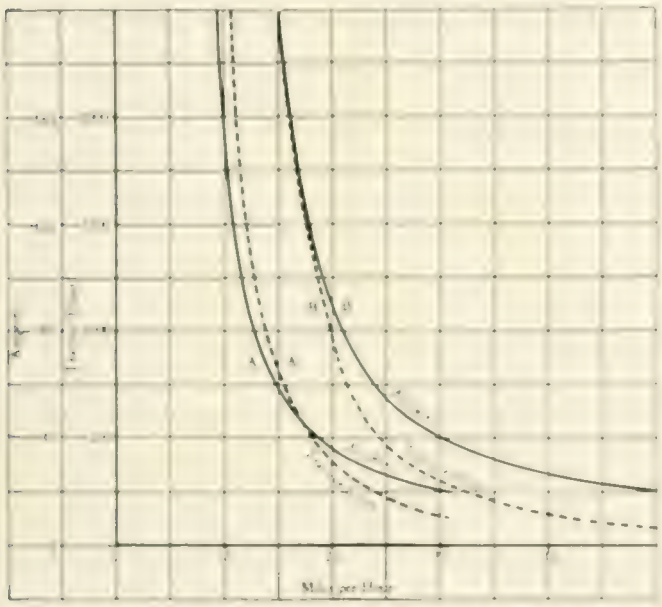


FIG. 1—SPEED, TRACTIVE EFFORT AND AMPERE CURVES

For 50 hp. 500 volt railway motor. *A* curves represent 15.69 gear ratio and 33 inch wheel. *B* curves represent 22.62 gear ratio and 33 inch wheels.

With these equipments, the question which arises is:—what would happen if an attempt were made to operate a train composed of one limited passenger car and one combination mail and passenger car, or a three-car train composed of these two cars, with a trailer added. In the case of the two motor cars, as both are of the same weight and must necessarily run at the same speed when coupled, a study of Fig. 1 will show the tractive effort and current for each motor at any speed. The curves *A* represent a 50 horse-power motor at 500 volts, with a 15.69, or 4.6 gear ratio and 33 inch wheel, while curves *B* represent the same motor with a 22.62 or 2.82 gear ratio with 33 inch wheels.

For example, if the cars are running at a speed of 10 miles per hour, at which speed they are still accelerating, the ampere curve *A* shows that each low speed motor will be taking 39 amperes and

the ampere curve *B* shows a current demand of 100 amperes for the motor geared for high speed. The tractive effort curve *A* at the same speed gives 440 pounds and *B* 1080 pounds for the respective motors. It can therefore be seen that at this speed the 22:62 geared motors are developing about 2.5 times the tractive effort and taking about 2.5 times the current of the motor geared with 15:69 ratio. In the same manner the respective amperes and tractive efforts for these two motors at any speeds can be determined.

The operation of the three-car train mentioned above is given in more detail by showing first, in Fig. 2, a regular run of both the limited-local single car, and the combination mail and baggage car with its trailer, while in Fig. 3 is given the results obtained by

TABLE I

ITEMS	Run No. 1	Run No. 2
Weight of car complete with load, tons	32	32
Weight of trailer complete with load, tons	20	0
Grade and curve resistance, lbs. per ton	4.5	4.5
Train resistance motor car, lbs. per ton	15	15
Train resistance trailer car, lbs. per ton	12	0
Trolley voltage average, volts	500	500
Length of run, miles	1	1.6
Length of stop, seconds	15	15
Schedule speed, miles per hour	18	25
Initial acceleration, miles per hour per sec.	1	1
Braking rate, miles per hour per sec.	1.5	1.5

operating these three cars coupled into a three-car train, on the same schedules. On Fig. 2, the speed-time curve marked *Run No. 1* together with current curve *A*, represents the run of the 32 ton combination mail and baggage car equipped with four 50 horse-power, 500 volt motors with 15:69 gear ratio and 33 inch wheel pulling the 20 ton trailer, and making a schedule of 18 miles per hour, with one stop per mile, under the assumption given in Table I.

From this curve it may be seen that the motors only use current for 135 seconds out of 200 seconds of the run, and coast for 40 seconds, or 20 percent of the total time. The root mean square current for this run is 89 percent of the continuous capacity of the motors. Consequently the motors have reserve not only in speed which will allow the car to make up lost time, but they can be operated continuously in this service with a reserve capacity for emergency conditions.

The speed-time curve marked *Run No. 2* with current curve *B* represents the regular 1.6 mile run of the 32 ton passenger car without trailer at a schedule speed of 25 miles per hour. This car is equipped with the same quadruple equipment of 50 horse power, 500 volt motors but with a 22:62 gear ratio and 33 inch wheel. The assumptions are the same as those used in *Run No. 1* as shown in Table I. This curve shows a coast of 81 seconds, or 35 percent of the total time, and that the motors are using current for 120 seconds or 52 percent of the total time. The square root of the mean square current in this case is 93.5 percent of the continuous capacity.

By using the curves in Fig. 1 the current and tractive effort of each motor at any period of the run in Fig. 2 can be obtained.

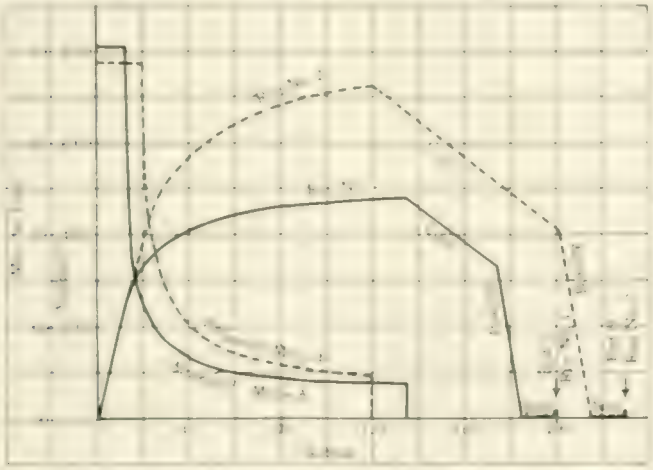


FIG. 2—SPEED-TIME CURVES FOR QUADRUPLE 50 HP 500 VOLT MOTORS ON 32 TON CAR

Run No. 1 and *A* curves, motor car with trailer, 15:60 gear ratio. *Run No. 2* and *B* curves, motor car, 22:62 gear ratio.

The accelerating current in each case is at the hourly rating of the motor, and is approximately the same, being 90 amperes in *A* and 88 amperes in *B* while the tractive efforts are 1538 pounds and 956 pounds respectively. While the period of straight line acceleration on the high speed car is much longer than on the low speed car with trailer, the balancing speed reached is higher in about the same ratio, being 38 miles per hour on *Run No. 2* as against 24 miles per hour on *Run No. 1*. In both of these runs the motors, under the conditions shown in curves *A* and *B*, are well selected for continuous service with a reserve in both capacity and speed.

Fig. 3 represents the results obtained by operating a train composed of the high speed car, coupled with the low speed car with its trailer, on the same runs given in Fig. 2 with the assumptions indicated in Table II. These assumptions are identical with those of the regular schedules used in Fig. 2 except that in *Run No. 2* it was necessary to reduce the time of stop from 15 to 9 seconds in order to make the schedule.

While the load on each motor in *Run No. 1*, Fig. 2, with the

two car trains is 13 tons per motor, and the load in *Run No. 2*, Fig. 2, with the single 32 ton car is eight tons per motor, it should be noted that with the three car or 84 ton train in Fig. 3 each motor has a load of 10.5 tons to handle. This is an increase of 2.5 tons for the high speed car and a reduction of 2.5 tons for the low speed car.

As the motor cars in this train must necessarily run at the same speed the proportionate amperes and tractive effort which each motor will produce at any of the speeds on the curve can be found from the curves in Fig. 1 as previously described. For example, the average tractive effort to accelerate this train under the assumption given above is 1 235 pounds per motor. From Fig 1 curve *A* we see that at 16.4 miles per hr. the 15.69 gear ratio motor gives 630 pounds tractive effort with 49 amperes, while

TABLE II

Items	Run No. 1	Run No. 2
Weight of each motor car, complete with load. Tons,	32	32
Weight of trailer..... Tons,	20	20
Grade and curve resistance..... Lbs. per ton,	4.5	4.5
Train resistance..... Lbs. per ton,	13	13
Average trolley voltage..... Volts,	500	500
Length of run..... Miles,	1	1.6
Length of stop..... Seconds,	15	9
Schedule speed..... Miles per hr.,	18	25
Initial acceleration..... Miles per hour per second,	1	1
Braking rate..... Miles per hour per second	1.5	1.5

the 22:62 geared motor gives 1 840 pounds tractive effort with 154 amperes and the average of these gives the required 1 235 pounds per motor. The heating effect on the motor is shown in curves *A* and *B* in Fig. 3. On *Run No. 4* the root mean square current is only 55 percent of the continuous capacity in the low speed motor while it is 141 percent in the high speed motor, although the current is only used 76 seconds or 38 percent of the run. The coasting period is also very long, being 110 seconds or 55 percent of the total time. The balancing speed of this train being 31.5 miles per hour, it was necessary in *Run No. 2* to cut out all coasting and also to reduce the time of stop in order to make the regular schedule. The current is here used for 200 of the 230 seconds or 97 percent of the time. The root mean square

current as shown in Fig. 3, Run No. 2, is 67 percent of the continuous rating for the slow-speed motor, curve *A* and 162 percent for the high speed motor as shown on curve *B*.

The above results show clearly that it would be impossible to run a train of this character under the regular service conditions without seriously overloading the motors on the high speed cars. The root mean square current, even at the balancing

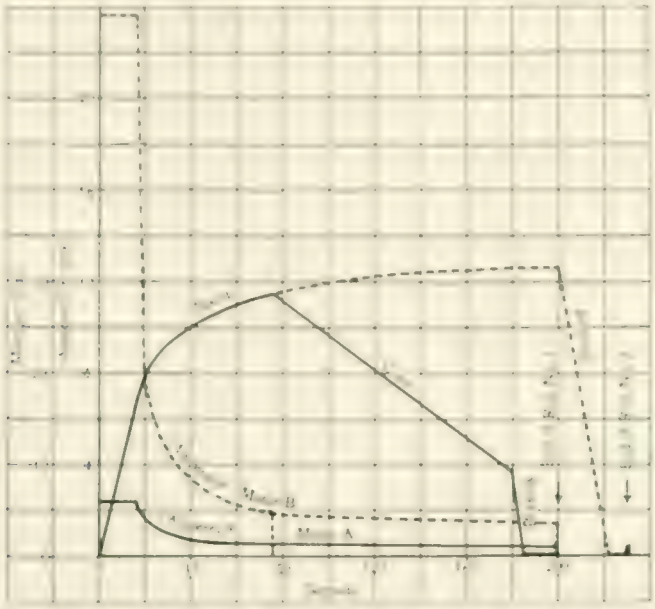


FIG. 3.—SPEED-TIME CURVES FOR QUARTER 50 HP. 500 VOLT MOTORS ON THREE-CAR TRAIN

Run No. 1 and *A* curves, 15.69 gear ratio.
Run No. 2 and *B* curves, 22.62 gear ratio.

speed of the train, is but two amperes below the continuous capacity of the motors. Consequently the only run which could be made at all within the capacity of the motors would be a limited run without any stops. While the above conditions represent a wide difference in gear ratio, they are such as exist on many roads, and the conclusions reached prove that the results from the operation of cars geared for different speeds should be carefully weighed before this is attempted.

CATENARY LINE CONSTRUCTION

WILLIAM SCHAAKE

The fact that a large number of electric railway companies have in the past seven years, adopted the single catenary type of overhead line construction as best suited to meet their service conditions, seems to indicate that this type of construction will eventually be a standard for interurban railways. As the majority of new installations will be of this character, articles treating of this type of construction, and explaining some of the fundamental features which are involved in the design, layout and erection would seem to be timely.

THE catenary type of trolley construction was first adopted in this country in 1905 in connection with high-tension single-phase railways and pantagraph trolley operation, as the direct suspension system was not adapted for high voltage insulation or for pantagraph trolley operation. The direct suspension construction has its limitations both mechanically and electrically.

When using pantagraphs, it was found necessary to have the trolley wire as level as possible with sufficient points of support so that the sag could be reduced to a minimum. After some experience was obtained with the catenary type of construction for single-phase operation, its many advantages were apparent when applied to 600 volt direct-current roads with wheel trolley operation. Longer spans could be used with a saving in poles. Porcelain insulation could be used with a low cost of maintenance and a high factor of safety. High speeds were permissible without having the trolley wheel leave the wire, and trolley breakages were almost eliminated.

At the present time, the majority of interurban roads using catenary type construction are also using wheel trolleys, which are somewhat cheaper than the pantagraph trolley and seem to operate satisfactorily. For the contact wire, both hard drawn copper and fairly low carbon steel wire of standard grooved section have been used with good success. Where high voltage alternating current is employed together with a sliding contact shoe, the steel contact wire gives more satisfactory operation than the copper wire, as with a hanger having a small amount of flexibility no kinking of the trolley wire will take place at the hanger, on account of the great stiffness of the steel wire. Where a steel trolley wire is used, however, it is necessary to have either an auxiliary trolley wire directly over the steel contact wire, or a copper messenger cable, in order to give the required conductivity. For direct-current work there are a number of installations using both a copper messenger cable and a hard drawn copper trolley. In this way the cost of feeder insulation and support may be eliminated.

TYPES OF CONSTRUCTION

Catenary line construction at the present time is represented by the following general types:

1—Steel messenger cable and copper trolley wire.

2—Copper messenger cable and copper trolley wire.

3—Copper messenger cable and steel trolley wire.

4—Steel messenger cable, steel contact wire and auxiliary copper feeder trolley.

Sub-Types—a—Single catenary construction. b—Compound catenary construction.

The steel messenger cable and copper trolley wire construction is best adapted for interurban roads operating on either 600 or 1500 volts, direct-current, and using a wheel trolley, and where it is desired to have a separately insulated feeder cable, in order that certain sections of the trolley may be cut out in case of emergency. The steel messenger has also a lower temperature coefficient than copper and there is therefore less variation in trolley height and alignment where a steel messenger cable is used. By using a high strength steel messenger cable a greater factor of safety is obtained than with the copper messenger cable, unless the copper messenger is made of a large size. This would of course result in additional load on the poles supporting the bracket arms or span wire.

CATENARY SPAN AND HANGERS

On tangent track it has been found that with bracket arm and cross span construction a maximum span of 150 feet gives satisfactory operation, and as this length of span is used almost universally it can be considered as standard. With bridge construction, spans of 300 feet can be used. Trolley wires should be No. 0000 standard grooved hard drawn copper wire and the messenger should be 7/16 in. diameter, seven-strand Siemens-Martin double galvanized steel cable.

The writer favors ten hangers per span where a 150 foot span is used. With this number of hangers the trolley wire is kept almost horizontal, and in case one hanger becomes loose satisfactory operation can still be maintained. Also, in case of a break in the trolley wire, there would be little danger of one end striking the rail and causing a short-circuit. The majority of roads which have recently been built have only five hangers per span or a minimum hanger spacing of 30 feet. While this number of hangers

has given good satisfaction, there is not the same factor of safety as with ten hangers per span. It might, however, be said that in some cases there would be less danger from accidental contact due to a broken trolley which has fallen to the road than one which is dangling in the air.

The curves given in Fig. 1 show the sag of the messenger cable at different temperatures varying from — 20 to 120 degrees F. With the hanger having a flexible connection at the massenger cable it is an easy matter to apply the proper tension to the messenger and trolley wire after the trolley wire has been hung and the

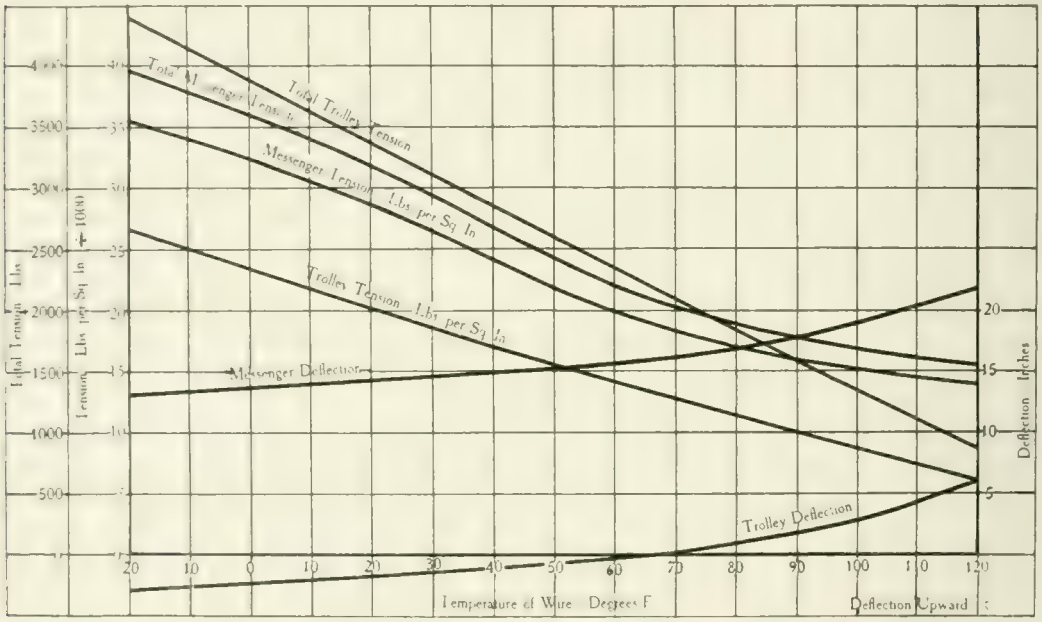


FIG. 1—MECHANICAL CHARACTERISTICS OF SINGLE CATENARY LINE CONSTRUCTION

No. 0000 trolley; span, 150 ft.; messenger $\frac{7}{16}$ in. steel cable; weight per ft. of span, 1.13 lbs..

Curves based on modulus of elasticity of copper, 16 000 000; modulus of elasticity of steel, 29 000 000; temp. coefficient, copper, 0.0000097; temp. coefficient, steel, 0.0000066.

messenger hangers have been applied. The hangers have been calculated for a messenger sag of 16 in. which is obtained at a temperature of about 70 degrees F. The messenger and trolley tensions which are given have been found to give the best results in practice. It is found that with a greater sag there is a decided tendency for side sway in hot weather, while with the smaller sag the tension in cold weather, with wind and ice load considered, might result in a break or in stretching the messenger cable. It will be noticed that there is only one temperature at which the trolley wire is absolutely straight. At higher temperatures a downward sag will be noticed, while at a lower temperature the trolley at the center

of the span will deflect upward. This upward deflection adds a load to the messenger cable, which has been considered in Fig. 1. It is essential that the trolley wire should be stretched as tight as possible without causing a load beyond its elastic limit at low tem-

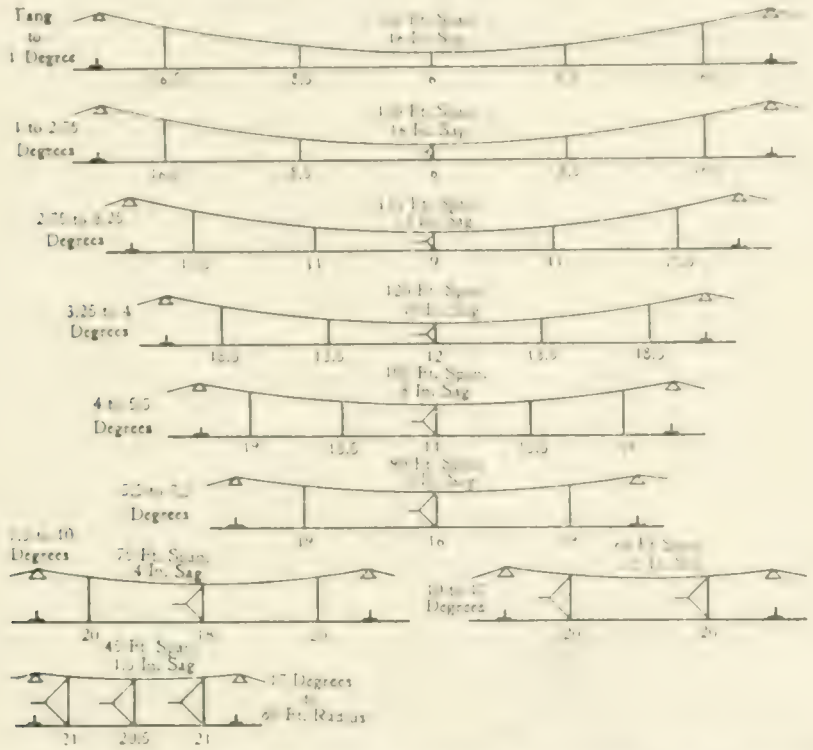


FIG. 2—SPAN AND PULL-OFF HANGER SPACINGS ON CURVES WITH STEADY STRAIN AT EVERY POLE

Sags given are at 60 degrees F. Center of messenger to center of trolley = 22 in. at bracket arm.

peratures. Otherwise in hot weather there will be considerable side sway of the trolley wire.

The hangers which should be used on a 150 foot span are indicated in Fig. 2, for tangent track or for curves up to one degree inclusive. For the one-degree curve it is necessary also to have a steady strain at each bracket arm to maintain the proper alignment of the trolley wire with reference to the center of the track. On tangent track steady strains are also required for every third or fourth pole in order to limit side sway of the trolley wire. For curves having a shorter radius than one degree, it is necessary to have shorter

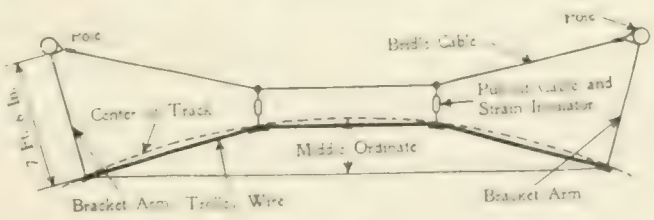


FIG. 3

spans and also make use of pull-off hangers to prevent excessive displacement of the trolley wire.

The pole spacing on curves should be such that the middle ordinate will not exceed 16 inches. By "middle ordinate" is meant (considering a plan view) the distance from the center of the track, at the middle of the span, to a straight line connecting the intersections of the two adjacent bracket arms with the center of

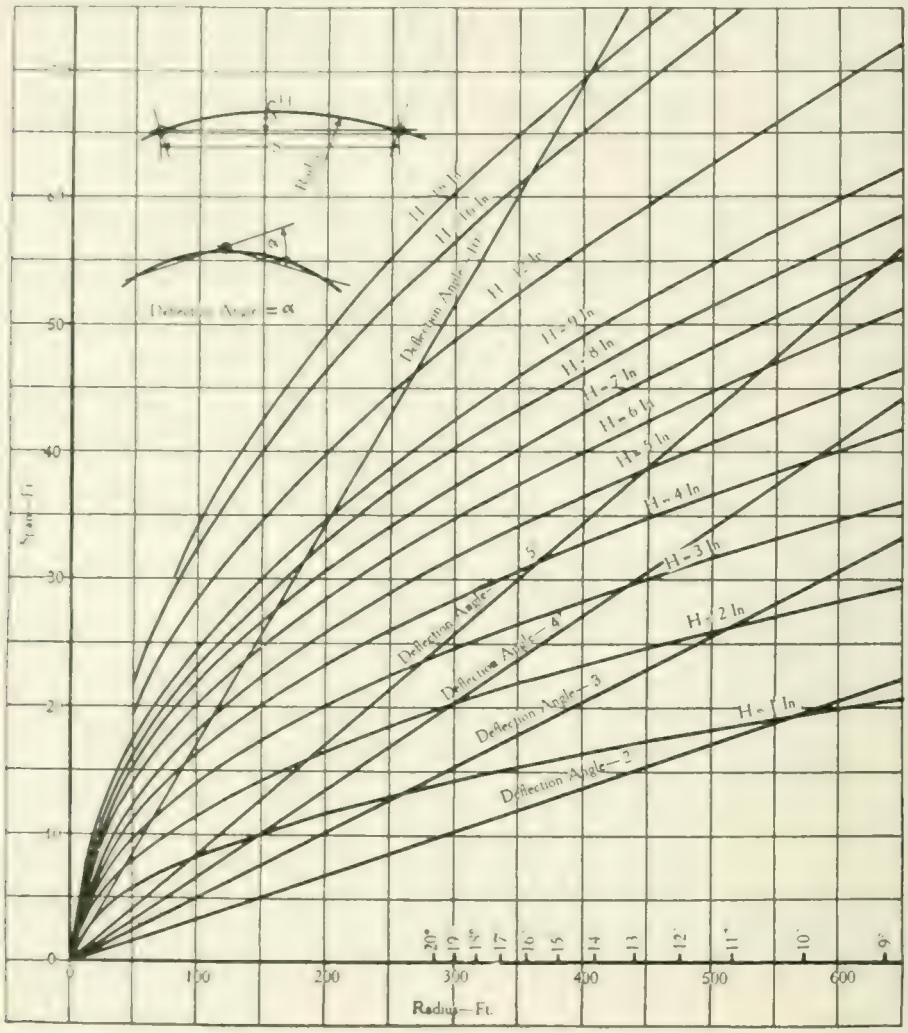


FIG. 4—POLE AND PULL-OFF HANGER SPACINGS ON CURVES
See also Fig. 5

the track, as shown in Fig. 2. For interurban construction, the standard distance from the center of the track to the inside of the pole is 7 ft. 6 in. Any increase in the middle ordinate results in additional tension in the bridle cable, as can at once be seen from Fig. 3, with resulting additional strain on the pole. While in some cases the middle ordinate can be made more than 16 in., the necessary calculations should be made to see that after allowing for the length of the pull-off cable, including the insulator, the

bridle cable will not be so straight as to be subjected to a considerable tension. In trunk line electrification the distance from the center of the track to the inside of the pole is made 10 ft. With this condition a middle ordinate of 2 ft. could be used for the pole spacing.

In order that the plane of the trolley wheel may not make too great an angle to the trolley wire it is necessary that pull-off hangers be added where curves have a shorter radius than one degree. The angularity of the trolley wheel with reference to the wire can be much greater for slow speeds than high speeds. The majority of roads now projected are for rather high speeds so that the pull-off hanger spacings given in Fig. 2 are for this class of service. With this pole spacing, the middle ordinate will not exceed 16 in., and with the addition of pull-off hangers the middle ordinate will not exceed 6 in. The angularity of the trolley wheel to the wire will not exceed 1.5 degrees for curves up to and including 5 degrees, 30 min.; the angularity will not exceed 2 degrees up to and including 7 degree curves, and will not exceed 5 degrees for curves having a radius up to and including 80 ft. While it may seem that a greater angularity of trolley wheel and trolley wire might be adopted and still have satisfactory operation, it must be remembered that the angles given above are obtained with the trolley wheel following a theoretical circular path, and with the pull-off hanger located in this path. Should there be side sway to the car or should the hanger be slightly displaced this angularity may be greatly exceeded and result in unsatisfactory operation due to the trolley wheel leaving the wire.

While the construction shown in Fig. 2 requires somewhat more material than a pull-off hanger spacing which allows greater angularity between the wheel and the wire, the operation will be found to be so much more satisfactory that the additional hangers required will be a minor consideration. For speeds not exceeding 25 miles an hour, satisfactory operation may be secured by using only the steady strains at each pole as shown in Fig. 2 and omitting the pull-off hanger. The 45 ft. span without the pull-off hangers in this case would be suitable only for curves of greater radius than 300 ft. For curves of shorter radius pull-off hangers would be required.

At the present time the most common practice seems to base the spacing of the pull-off hangers on the length of the middle ordinate, but the better practice would seem to be to base this

spacing on the maximum angularity of the plane of the trolley wheel relative to the trolley wire. The satisfactory operation of the trolley depends on this angle. This can readily be appreciated by laying a piece of trolley wire in the groove of the wheel and then making the wire assume an angle relative to the plane of the wheel. When this angle exceeds 10 degrees, the trolley wire will

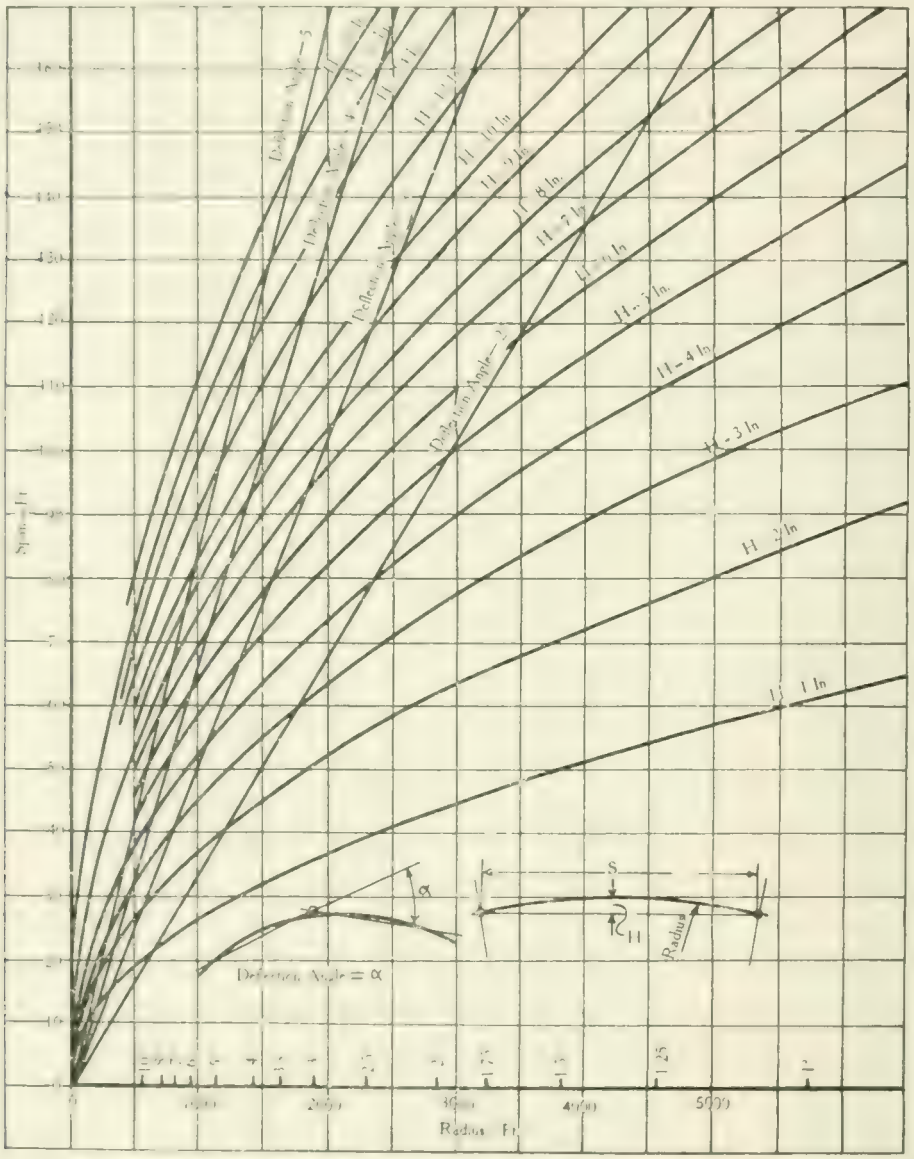


FIG. 3—POLE AND PULL-OFF HANGER SPACINGS ON CURVES
See also Fig. 4.

rise from the bottom of the groove; and this is the action which is liable to take place in practice at the trolley hanger. The best practice would be to locate the pull-off hanger directly in the theoretical path of the trolley wheel instead of equalizing the displacement of the trolley wire at the hanger and between hangers, as is frequently done.

It is sometimes necessary to use special spans and hanger spacings. In order to determine at once the middle ordinate and angularity of the wheel with the wire, the curves shown in Figs. 4 and 5 have been developed.

The relation of the trolley wheel to the wire is shown in Fig. 6.

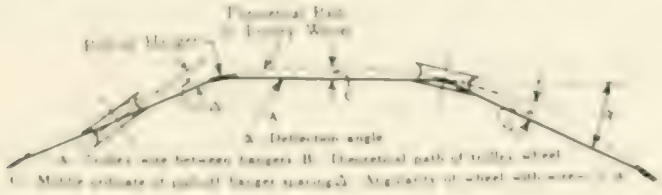
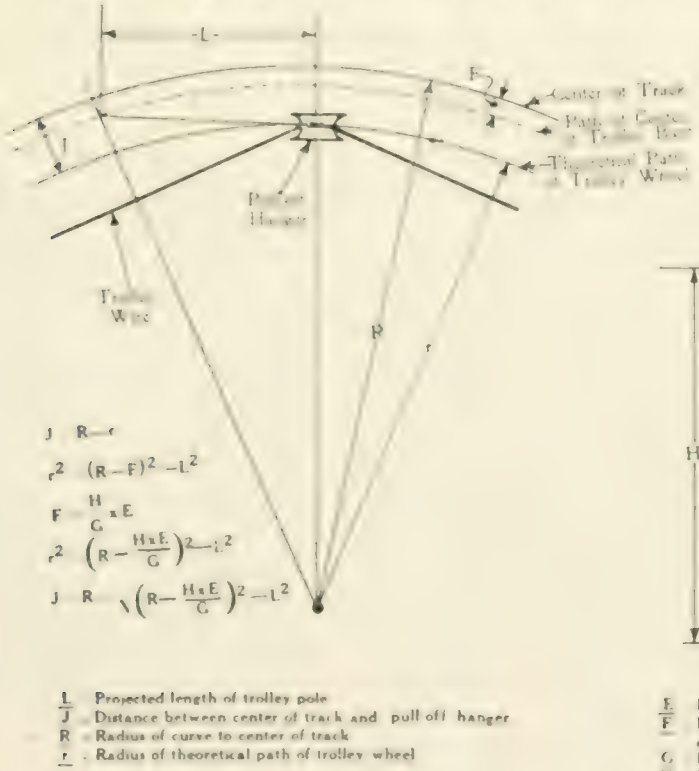


FIG. 6

The angle Δ refers to the maximum angularity of wheel with wire

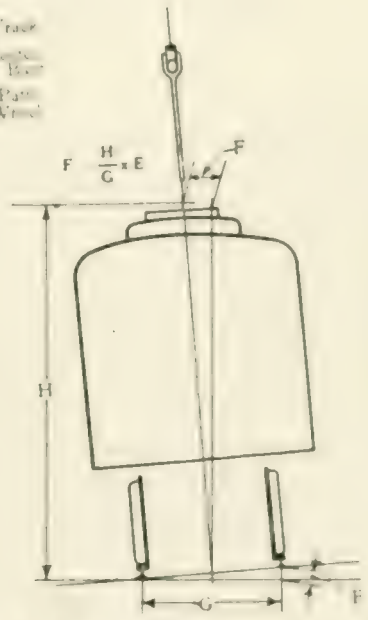
As can plainly be seen from this figure, the angularity of the wheel with the trolley wire when the wheel is passing the pull-off hanger is equal to one-half the deflection angle given in Figs. 4 and 5.

When aligning the trolley wire, due consideration should be



L Projected length of trolley pole
J Distance between center of track and pull off hanger
R Radius of curve to center of track
r Radius of theoretical path of trolley wheel

FIG. 7



E Elevation of rail
F Displacement of trolley base, due to elevation of rail
G Distance from center to center of rails
H Height from rail to trolley base

FIG. 8

given to the elevation of the outer rail on curves, and the corresponding projected length of the trolley pole.

The formulæ accompanying Figs. 7 and 8 indicate a method for finding the amount by which the pull-off hanger should be dis-

placed toward the center of the curve to allow for the variation in effective length of trolley pole and elevation of the outer rail.

For example, consider a three degree curve having a radius of 1 910 ft.; the maximum speed to be 40 miles per hour.

From the formula "$E = 1.7857 \frac{V}{R}$", for a standard track gauge of 4 ft. 8 in., the elevation of the outer rail will be 3-5/16 in. (V = speed in ft. per sec. and R = radius of curve in ft.).

$$J = R - \sqrt{\left(R - \frac{H \times E}{G}\right)^2 - L^2}$$

Where, R = 1910, H = 13 ft. (av. height interurban cars), $E = 3\frac{5}{16}$ in., G = approx. 5 ft. center to center for standard guage track 4 ft. $8\frac{1}{2}$ in., L = 14 ft. = Projected length of 16 ft. trolley pole, making 30 deg. angle with car roof.

$$J = 1910 - \sqrt{\left(1910 - \frac{13 \times 3\frac{31}{512}}{5 \times 12}\right)^2 - 14^2} = 0.77 \text{ ft.} = 19.24 \text{ inches.}$$

For any given car and trolley curves can be plotted for the radius of curve and elevation of outer rail. From these curves the displacement can then readily be found.

SAFETY DEVICES FOR ELECTRIC RAILWAY EQUIPMENTS*

J. J. SINCLAIR

IN LATER TYPES of car equipment especial attention is being given to devices which will help to prevent accidents. Much is being done in door designs, and car steps are being lowered as much as possible, along with changes in car-framing. Many passengers have been injured by boarding cars before they come to a stop and by alighting while the car is still moving. A great deal of valuable time in preventing accidents is lost by the conductor in getting the proper signal to the motorman to stop when he sees a passenger in danger, and the time taken by the motorman to get power off the car and set the brakes in emergency. With low current, low voltage multiple control circuits, all of these difficulties may be overcome. Some of the important safety devices are considered in the following.

DOOR SIGNALS

Cars equipped with either air-operated or lever-operated doors may have a small interlock designed to close the control circuit when the door is shut. By connecting the interlocks on the various

*Extracts from a paper read before the Keystone Railroad Club at Scranton, Pa., Sept. 16, 1912

doors in series, it is necessary that all doors be closed before the motorman can start the train, as it is impossible to close the main switches until all of the interlocks have completed the control circuit. Where cars are run in trains, a small drum switch is mounted on the coupler dash socket, so designed that when the coupler socket cover is raised to permit installation of the jumper, this drum switch which is in series with the door interlock, opens and the circuit is only completed through a correspondingly closed switch on the rear dash of the rear car and thereby the motorman can only get the use of the control circuit when all doors are closed in the train. The various wires for these circuits are carried in the regular train line control cable.

Should it not be desirable, however, to couple in the control circuit in this way, the motorman may get the signal from the pilot light of the same circuit. This door interlocking device will save many accidents and permit the conductors to proceed with the collecting of fares, etc., without the usual danger when he is not right at the door at the time of starting the car.

INTERLOCKING POWER AND DOOR

Again, it is very desirable to be able to prevent the opening of doors until the car comes to a standstill or nearly so. This is taken care of in air-operated doors by a small relay connected across the armature of one motor, so that the voltage generated by the residual magnetism will hold the relay contact open, while the armature is revolving, the relay being connected to the line through a resistance when power is on the motor. The valve controlling the air to the door is magnet operated and the relay contacts are in series with this magnet. The door then cannot be opened until the relay contacts are closed, or when the car is not in motion. The relay may, however, be adjusted so that the car may run at some predetermined low speed without opening the circuit.

CONDUCTOR'S EMERGENCY VALVE

A small conductor's emergency valve has been designed so that the conductor can bring the car to a standstill in the shortest possible time, doing away with the time lost in getting signals to the motorman by bell or otherwise. This valve not only applies the brakes, but shuts off the power. It is operated by a pull rod connected to a small switch in the control circuit and to the stem

of the air valve. When the conductor pulls this rod, the switch closes and the emergency valve opens. The closing of the switch short circuits certain train line wires and the main motor switches in the train immediately open. This interlocking is positive and will prevent many accidents. The motorman cannot start the car or train again until the conductor has released the valve.

DEAD MAN'S EMERGENCY

With the later type of master switches used with unit switch control equipment, emergency handles may be obtained. The use of these handles necessitates special design of the master switch, but the advantage is gained in having the dead man's release. With this master controller, an additional button on the handle knob operates, through a small toggle, a small emergency pilot valve and a pair of control contacts in the master controller. It is necessary when operating the car to keep this button pressed down against the handle knob in order to avoid setting the brakes in emergency and opening the control circuit. Should the motorman become ill or for any reason release his hand from this button, power will at once be cut off and the brakes applied, and the controller handle must be returned to the "off" position again before power can be applied to the motors. This point will be appreciated since when motormen are careless or suddenly become unable to perform their duties and release their hands from the older type of controllers, accidents are more liable to occur.

RESETTING OF CIRCUIT BREAKERS

In older types of controllers it is possible to leave the controller in a notched-up position when the circuit-breaker opens and put power back in the motors as soon as the breaker is closed. Many cases have occurred where motormen would throw the handle back to first or second point, throw in the circuit-breaker and start the car just as a passenger steps from car. Most of these cases occur in city service. With the later types of unit switch control it is necessary to throw the handle to the "off" position before the circuit-breaker can be reset.

UNIT SWITCH CONTROL

AARON B. COLE

WITH THE INCREASE in exacting operating conditions demanded of present day electric railways, it was found necessary that power operated controlling apparatus be developed, which would not be entirely dependent upon the trolley for current for actuating the switches carrying the heavy currents. As this existing power should of necessity be of a very reliable character, compressed air, with its unparalleled record of reliability in the air-brake, switch and signal fields, is employed. Also since nearly all electric cars are now supplied with air brakes, the utilization of compressed air in connection with electric railway control apparatus was the obvious result.

The use of compressed air in closing, and of a heavy spring in opening contacts that carry heavy electric current secures many advantages not possible by any other means, such as high pressure between contacts, which is constant regardless of the trolley voltage; a substantial reduction in wearing away of metal and welding together of contacts. Also since the contact pressure is very positive the contacts have a high carrying capacity and may be narrow, thus permitting effective magnetic blow-out action to take place at the switches when opening, since the air-gap between blow-out coils is a minimum. Remote control switching equipment of the type described in this article is used on roads operating at 500, 600, 1 200 or 1 500 volts direct-current and also on single-phase alternating current. It presents a number of advantages over the platform type of controller even when used for single car operation, such as:—

1— Switches and contacts are assembled in one compartment, with all heavy current carrying parts located beneath the car. Circuit breaker action takes place beneath the car and is not visible to the passengers.

2—Each circuit breaking switch or contact is arranged in an isolated asbestos or vulcabeston insulated section. Each switch is provided with a powerful blow-out more effective than the average car circuit breaker. A short circuit is opened by two or more switches in series, the duty of handling heavy currents not being imposed on any one switch.

3—A very low current is used in the platform controller so that all former platform controller burn outs, etc., are eliminated.

4—The controller occupies but very small space on the car platform.

5—There is approximately 100 pounds or more pressure between each pair of the heavy current carrying contacts. Heavy cylinder springs insure the positive opening of switches.

6—Less wire is required for motor circuits. All motor current wires are located beneath the car and are thoroughly protected against the danger of fire.

7—The apparatus is designed on the unit principle so that all parts may be readily inspected and easily replaced. The arrangement of the moving parts is such that a wiping action of the contact tips is obtained, so efficient in its operation that long life of the contact tips may be obtained with no attention in the way of filing or trimming. The equipment is so arranged that the car barn men can easily maintain it. It has the working parts accessible and as few as possible, and wearing of the working parts does not affect the efficiency or reliability of operation.

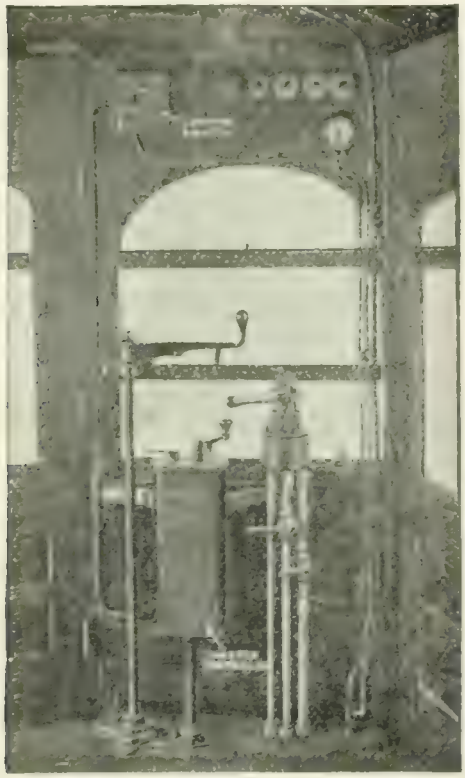


FIG. 1—CAR INTERIOR, SHOWING MOTORMAN'S CONTROL EQUIPMENT

During the first few years of operation a prejudice existed against the pneumatic control on account of the belief that the pneumatic parts would collect moisture and freeze during the winter. It has been demonstrated during several severe winter seasons in northern cities that the question of freezing is negligible if the cars have the reservoir and piping properly arranged. The objection has also been raised that inasmuch as the control depends on the air supply, all cars would be disabled if the air compressor failed. This, of course, is true, but is regarded by many railway managers as an advantage, or at least as not in any way objectionable on account of the fact that when the compressor fails the air brakes are disabled, and it is unsafe to operate a car with the power brakes disabled. In cases of this kind cars equipped with unit switch control may be coupled with the following car

when it arrives and the two be operated as a multiple-unit train; that is, the motorman on the head car controls and operates both cars. Where desired, an emergency or spare reservoir may be used, sufficient to take the car to the terminal or at least to a telephone siding or junction, in case the compressor fails. However, the great reliability and economy of this control on over a hundred roads demonstrates that this feature is negligible.

TRAIN OPERATION

In addition to the advantages of the unit switch control for single car operation, one of the most important points in its favor is the ability to control two or more cars simultaneously. Multiple-unit operation, which is made possible by unit switch control, has a number of characteristics that greatly enhance the operating efficiency of a system. Where multiple-unit trains are employed it is usually not necessary to have either cars or equipment as large as if they were operated singly at all times. In the effort to avoid train operation the size and equipment of interurban rolling stock has been increased to huge proportions. These big cars run most of the day with a small number of passengers for the sake of being able to handle the fifty or sixty who must be provided for on a few special trips. To make proper use of mulitple-unit trains a size of car more nearly suited to the average load should be employed and the capacity increased by coupling up when necessary. With equipments properly proportioned on this basis, there are probably few roads where two-car trains could not be run. Some roads may hesitate to employ multiple-unit trains on account of a supposed inadequacy of sub-station and feeder capacity. The power requirements can be kept within very reasonable limits by proper training of the motormen. The cars on a certain line were equipped with two 150 horse-power motors, or a total of 300 horse-power each, and geared for a maximum speed of about 50 miles per hour. Great care had been taken in training the motorman on this line, and as a result the maximum current per car rarely exceeded 350 amperes. Where the motormen have not been instructed, currents of over 600 amperes have been noted on cars with the same equipment. It is quite evident from these figures that two-car trains in the hands of the first set of men could have been operated with peaks little or no higher than those caused by single cars in the hands of the second set.

Further, multiple-unit cars are able to move independently, and the making up of a train can be done with a minimum shifting, as

compared with the use of trailers. At stub end terminals either car may be used for the leading car. If the motors were originally correctly applied there will be no danger of overloading them, since the weight handled per motor is uniform. Thus, it is possible with this uniform motor loading to apply the motors more efficiently as to size and gear ratio, than if trailer operation had to be provided for; and smaller motors, geared for lower speeds, can be used for a given car schedule. Thus, for handling varying crowds, and still maintaining a close schedule, the employment of trailers, even under favorable circumstances, becomes a temporary expedient when compared to multiple-unit operation.



FIG. 2—MASTER CONTROLLER FOR TYPE HL UNIT SWITCH CONTROL SHOWN IN FIG. 3.

The advantages of train operation are not by any means confined to saving in power and flexibility of equipment. The operation of two single car units requires four men to two cars, while the operation of a two-car train requires only three men for two cars, thus effecting a saving of 25 percent in labor. Where the traffic is necessarily congested, as in the center of a city during the rush hour periods, single car operation does not permit of the maximum use of the tracks.

TYPES OF UNIT SWITCH CONTROL

Four types of unit switch control are in common use, the classification depending upon the method of applying the power to the unit switches. These are:—

I—Hand operated, line voltage control, known as HL. The master controller has as many points as there are control positions, and a separate reversing handle.

II—Automatically operated line voltage control, known as AL. The master controller has three points forward and three reverse, corresponding to switching, series running and parallel running.

III—Automatically operated battery voltage control, known as AB.

IV—Hand operated, battery voltage control, known as HB.

These types of control are all suitable for multiple-unit operation and each possesses all the advantages enumerated for the unit switch control.

The HL Control has been especially designed for service where apparatus of a simple character is particularly desired. On this

account, various features, such as automatic acceleration, bridging transition, etc., have been omitted. These features are not essential for the success of service for which the equipments are intended, particularly where simplicity of parts is desired. This is the type of control which is in most common use for city and light interurban service where light weight and cheapness are prime considerations, where the trolley voltage is fairly uniform and where automatic acceleration is not necessary.

This type of control is so arranged that trains may be made up of two or more cars, but generally not exceeding five motor cars

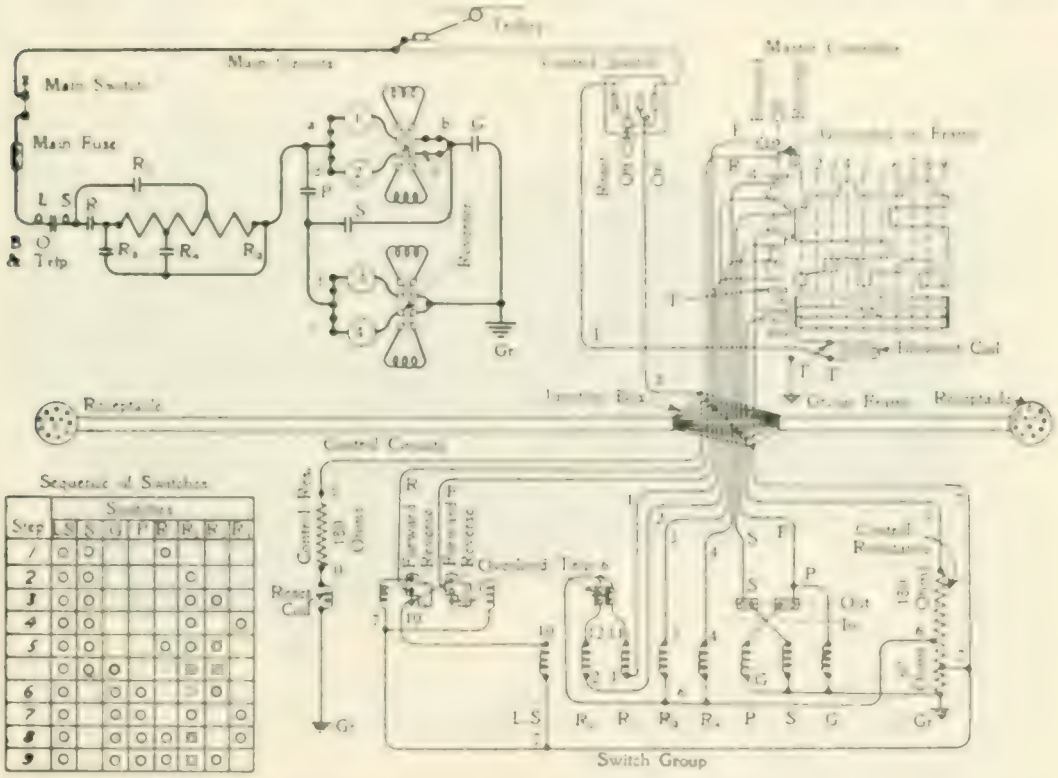


FIG. 3—DIAGRAM OF CONNECTIONS

Four-motor equipment, with HL type of unit switch control, in which acceleration of the car or locomotive is secured by means of a hand-operated drum controller, and in which the magnet valves of the switches are operated by current tapped from a resistance connected directly across the line.

and the train may be operated from either end of any motor car. The main circuit connections are made by means of a number of independent pneumatically operated switches known as unit switches, each provided with a strong magnetic blow-out, and normally held open by a powerful spring.

In small equipments all of the unit switches are mounted in an iron frame known as the switch group, and two of the switches in the group act as circuit breakers. Large equipments are provided

with a two-unit line switch mounted on a separate frame from the switch group, which performs the functions of an automatic circuit breaker. The overload trip that controls the opening of all switches in case of overload or short-circuit is mounted on the end of the switch group, or line switch when separate from the switch group. This trip is acuated by the magnetic pull produced by one of the blow-out coils, which is in the main circuit. When a predetermined current value is exceeded a plunger carrying two contact discs breaks the control circuit which causes certain switches to open in the line switch and switch group. This plunger when drawn in

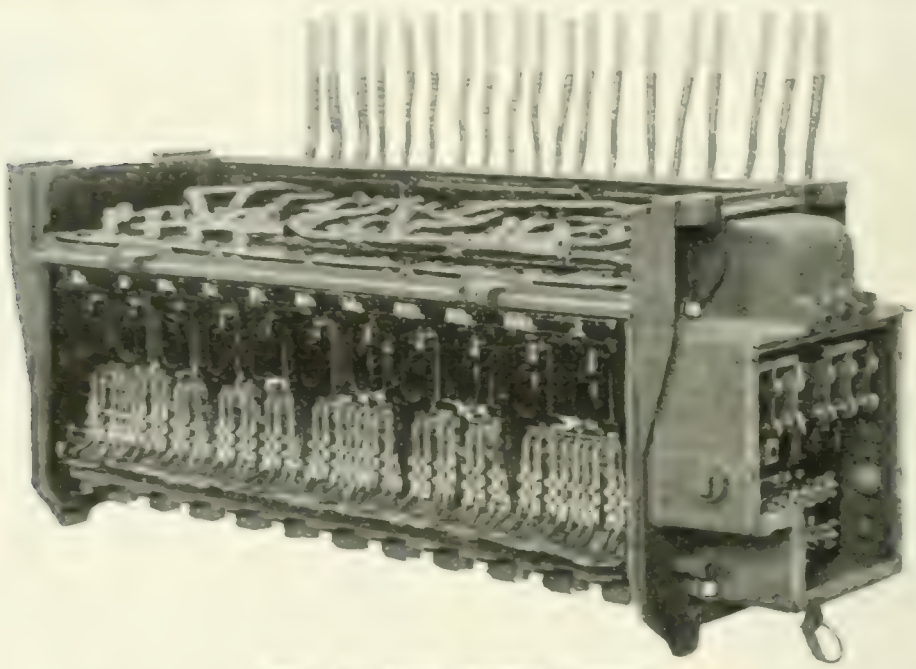


FIG. 4—UNIT SWITCH GROUP
For type AL control shown in Fig. 6. Cover removed.

is held by a latch and cannot be released until the control switch in the cab is reset. This can only be done when the controller is on the "off" position. This trip can be also reset by pulling a wire hanging through the overload trip cover, attached to the relay armature which, when pulled, releases the plunger from the hold of the latch, and again establishes the control circuit through the trip. Then to energize the control circuit the control switch need only be placed in the "on" position and the master controller notched up to start the train.

A pneumatically operated reverser controls the direction of operation of the car. This reverser consists of two pistons similar to those attached to the unit switches, which serve to move the reverser

drum to the forward or reverse position. The air-brake system furnishes compressed air for operating the reverser and switches.

Junction boxes are used for making connections between the train line and branch control circuit to the various pieces of apparatus on each car. Connecting into these junction boxes is a multi-conductor train line which extends the length of each car and ends in a multi-point receptacle at each end. The train line is made continuous throughout a number of cars by connecting adjoining train line receptacles with a multiple-conductor train line jumper.

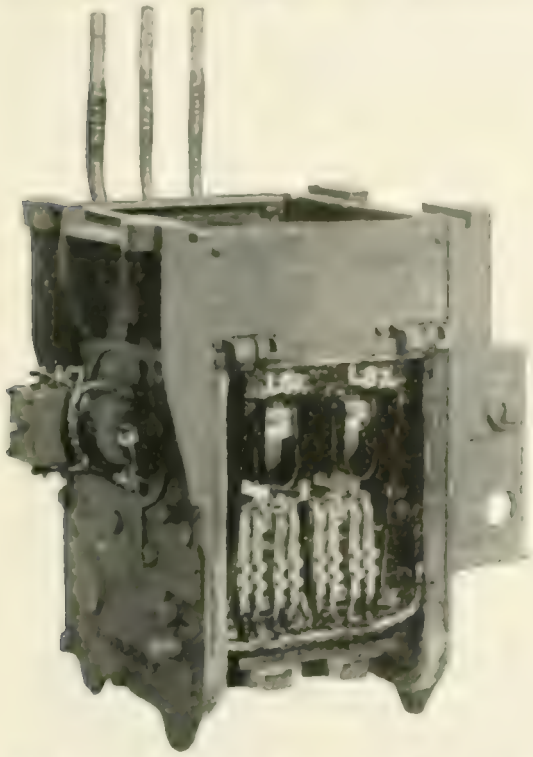


FIG. 5—LINE SWITCH FOR TYPE AL UNIT SWITCH CONTROL SHOWN IN FIG. 6.

The train line is rendered safer and the whole equipment more reliable by the arrangement of the control resistance. This resistance is not connected in series with the magnet coils, but is connected in shunt across the line when the master controller is on and the magnet coils are operated from low voltage taps. Thus, normally, only one of the train line wires carries full trolley voltage while the remainder are subjected to voltage of one-third or less, instead of all the auxiliary circuits being operated at full line voltage. The master controller consists of a small drum controller with the main and reverse handles interlocked which precludes any false operation.

The extensive application of this type of control has been due to its simplicity, accessibility, ruggedness, and powerful action, embodying the fewest and simplest parts possible.

Except on large equipments, the switch group and the reverser cover the entire main circuit parts. The arrangement of these as separate items instead of in the same frame enables both to be made much more accessible for inspection or repairs and permits a better balance to be obtained when the apparatus is mounted on small cars.

AL Control—This type of control has three important advantages, due to its automatic acceleration feature, namely:—

1—Safety to motor equipment.

2—A predetermined rate of acceleration.

3—Comfort to passengers (with high powered motors).

For operation on elevated roads, in subways and trunk line interurban service, particularly with trains made up of a number of cars equipped with high power motors, where no severe grades are encountered, this type of control is especially adapted. In service of this kind, the schedule is very inelastic, and under close headway, making it necessary that all trains keep their proper headway at all times; the last being possible by use of the automatic acceleration features of this control.

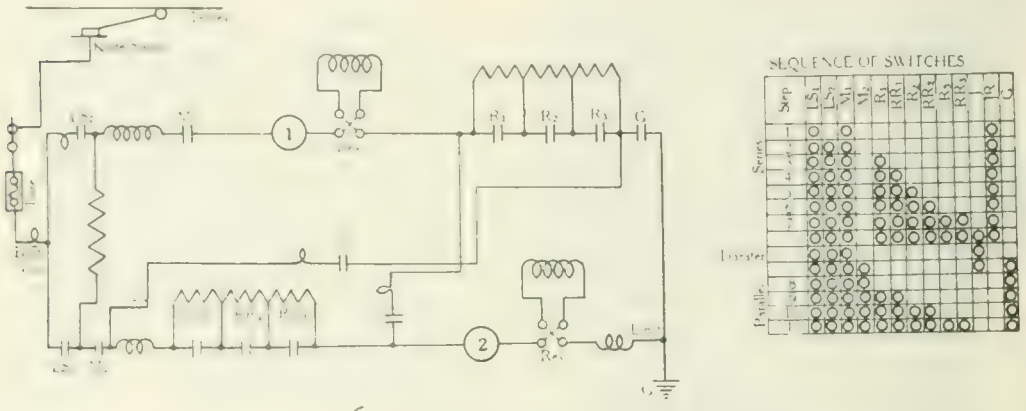


FIG. 6—DIAGRAM OF CONNECTIONS.

For two-motor equipment, with type AL unit switch control in which acceleration of the car or locomotive is secured automatically, only three operating positions being given by the master controller, corresponding to "switching," "series," and "parallel" connections of the motors; the valve magnets of the unit switches are operated by current tapped from a resistance connected directly across the line.

The essential difference in this equipment over the hand operated control is that the acceleration of the train is secured automatically. The master controller has only three positions, which are "switching," series running, and parallel running. The "off" position is in the center. The unit switches are provided with interlocks which are electrically connected with the valve magnets in such a manner that the closing of one switch energizes the magnet of the next, thus producing automatic progression of the switches, under the direction of the limit switch. This limit switch controls the rate at which the resistance is cut out of circuit, so as to give uniform accelerating current. This produces smooth and econom-

ical acceleration and also prevents abuse of equipment by accelerating in excess of the predetermined rate.

The limit switch consists of a solenoid operated by the current of one motor or pair of motors. When this current exceeds a predetermined limit for which the switch is adjusted, the circuit through a pair of contacts in the operating circuit is opened. The circuit remains open, so that no further unit switches can close, until the accelerating current falls below the predetermined limit when the control circuit is again closed, thus allowing the unit switches to continue their progression. Should the overload trip open the control circuit, this is reset by the plug switch in the master controller, the plug being attached to the controller by a chain.

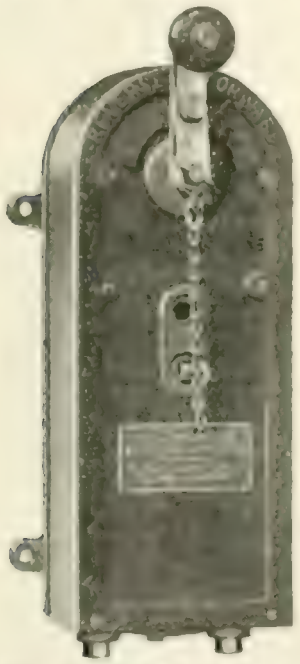


FIG. 7—MASTER CONTROLLER FOR TYPE AL UNIT SWITCH CONTROL SHOWN IN FIG. 6.

AB Control uses currents from a storage battery, at approximately 15 volts for the control circuits. For elevated and interurban lines that operate trains of three or more cars, and where the profile of the latter type of road is generally level, this control apparatus may be used to advantage. It is also excellently adapted to single-phase railway operation, for the batteries supply the direct-current necessary for energizing the control circuits. Because of its advantages this method is used by many important systems for multiple-unit train control. Among these properties are: New York, New Haven & Hartford Railroad; the Long Island Railroad; the Brooklyn Rapid Transit Company; the Metropolitan Elevated Railway of Chicago; the South Side and the West Side Elevated Railways of Chicago, and the Pacific Electric Railways Company of Los Angeles, Cal. Some of the advantages of storage battery control are:—

1—Should brakes fail due to "trolley off" or any other cause, the motors can be "bucked," providing an emergency brake of great effectiveness.

2—Fuses are unnecessary in the control circuit since low voltages only are used. Danger of fuses blowing, and rendering the control inoperative during emergencies is thus eliminated.

3—The possibility of insulation breakdowns in the train line or jumper cables which might result in false operation of the controller is minimized. This is because of the low control voltage.

4—There is no necessity for conductors, fuses or switches at line potential, on the car platform.

5—Signal bells and tail lights can be operated from the storage battery.

FIELD CONTROL

Field control is a system of regulating the speed of a direct-current series motor by varying the effective field turns. This is effected by employing motors having a greater number of turns in the field winding than is ordinarily employed, and by arranging the control so that on certain notches a portion of the field winding is cut out of circuit. With motors thus equipped, cars or locomotives can start heavy loads with small current consumption, and

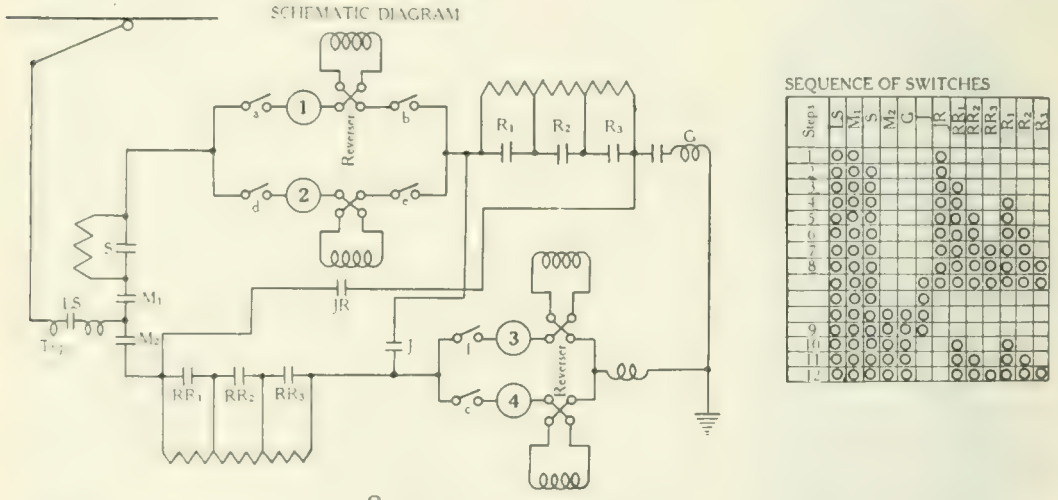


FIG. 8—DIAGRAM OF CONNECTIONS.

Four-motor equipment, with the type AB unit switch control in which acceleration of the car or locomotive is secured automatically; corresponding to the type shown in Fig. 6, except that current for operation of the valve magnets is furnished by a 15 volt storage battery.

can also run efficiently at high speed when desired. A two-motor equipment has four efficient speed notches on the controller which enables the same equipment to be operated with a minimum loss in either local or high speed service. Trains may be started with much lower accelerating currents and will run on resistance a smaller portion of the time. Thus a double saving ensues. When the entire field winding is used, the motor can produce large tractive efforts at low speeds with moderate current input. This enables it to start and accelerate a car very smoothly. When a portion of the field winding is cut out, the characteristics of the motor are modified just as if the gear ratio had been instantaneously changed.

When connected in this way, the motor attains higher speeds than with the full field winding in use, and while this "normal field" is not so well adapted for starting the car, it is much better adapted for producing a high maximum car speed. In this way a given equipment can be made to operate more nearly under ideal conditions both in starting and in free running than if it must be arranged on some compromise basis.

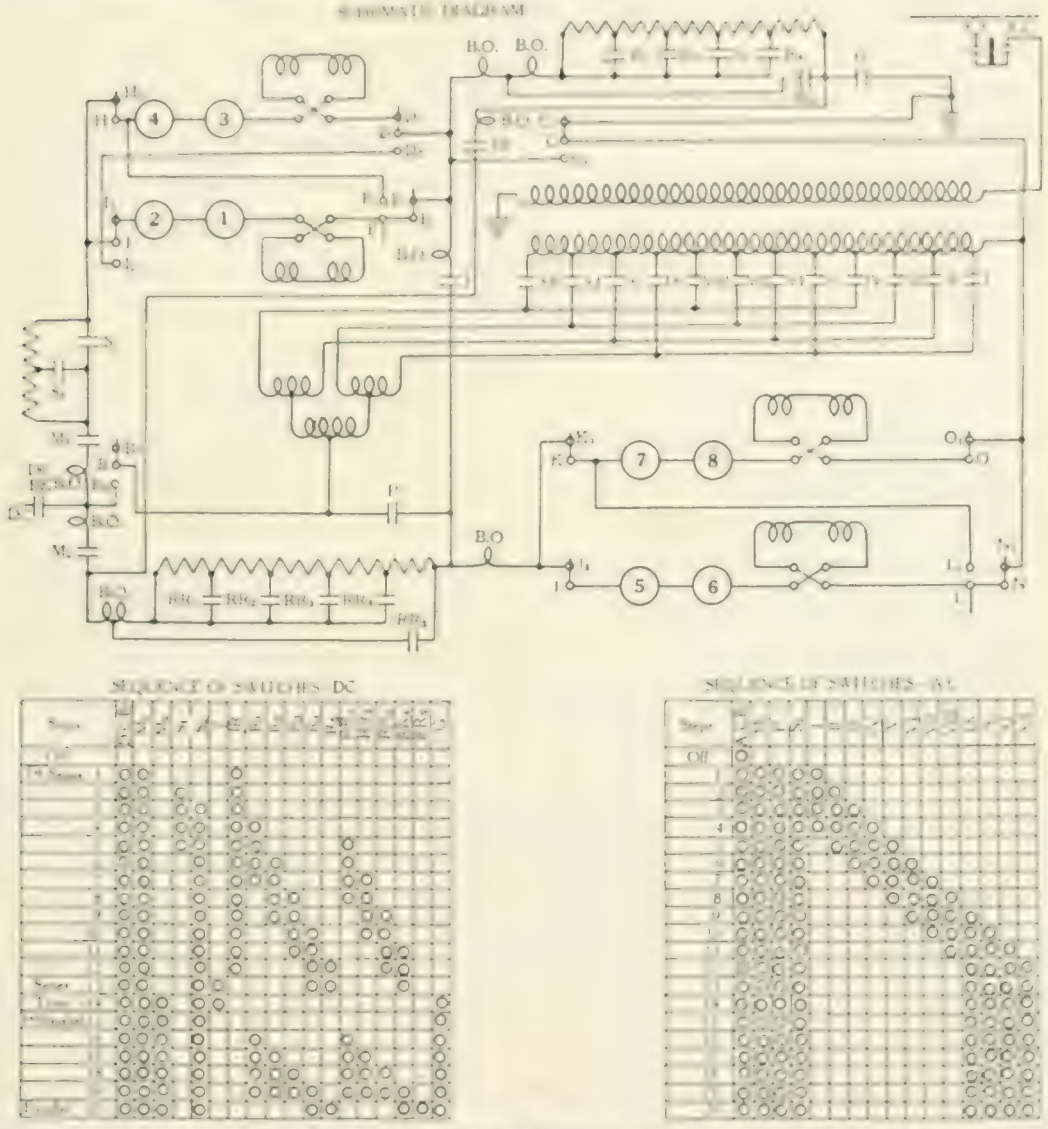


FIG. 9—DIAGRAM OF CONNECTIONS OF NEW YORK, NEW HAVEN & HARTFORD LOCOMOTIVE

Equipped with type HB unit switch control in which acceleration is secured by means of a hand-operated drum controller, and in which the magnet valves of the unit switches are operated by current from a 15 volt storage battery.

This arrangement is particularly advantageous for city and suburban service where a large number of service stops are made, and under such conditions there is, with field control, a saving of

8 to 15 percent in power consumption. Field control is also advantageous for interurban equipments which are sometimes operated in local and sometimes in limited service. Its use in such cases enables a single motor equipment to be readily arranged so as to give good results in both classes of service.

Field control insures a minimum of operation on resistance. It virtually produces a high speed equipment which has an extremely small rheostatic loss in starting. The saving in energy will depend largely on the amount that is ordinarily lost in resistance. Inasmuch as higher speeds are possible, the time of coasting is usually longer with field control, and another saving is thereby effected through the reduction of braking losses. There is also a slight economy in weight, as a decrease in resistance loss insures that there will be less resistance to carry. In some cases, with field control, the motor is also lighter.

The first important installation of field control on locomotives was that on the passenger locomotives placed in service by the New York, New Haven & Hartford Railroad five years ago. When operating in the direct-current zone the speed is regulated by field control. The method proved so satisfactory that, when the time came, the same plan was adopted for the locomotives for the Pennsylvania Railroad Company's New York City extension and its success has been equally great with these engines. Through the use of field control the Pennsylvania locomotives have the advantage of both high-speed and low-speed machines. The full field gives an enormous tractive effort at slow speeds with relatively small current and the normal field permits the locomotive to haul comparatively heavy loads at high speeds, enabling the motors to efficiently operate over a very wide range of speed. Numerous installations with this type of control have since been made on both city and interurban lines, and its fitness on commutating pole motors has been demonstrated.

Any of the unit switch systems of control can be equipped with field control, the type designation being formed by adding the letter F to the unit switch type designation. The three in most common use are the HLF, ALF and HBF.

HLF Control—In case a road wishes to standardize an equipment or wishes to still make use of the advantages of HL control, HLF control may be adopted. This combines the advantages of both HL and field control. With an equipment of this kind, the acceleration of the car or train is entirely under control of the motorman, and at the same time, by the use of field control,

economy in power is effected, and the same car can be used for local and limited service. The last is important in that often only gears and pinions for one gear ratio need be carried. This type of control is adapted to city and interurban service, for either single car or train operation.

ALF Control—This type of control is applicable to the same kind of service in which AL equipments are operated, namely, multiple-unit train operation on elevated roads, in subways and in trunk line suburban service.

HBF control is well adapted to locomotive service and in addition has the advantage of the field control feature which gives a flexible equipment and affects economical power consumption. A notable application of this type of control is to be found on the Pennsylvania Railroad locomotives.

When the Pennsylvania Railroad locomotives were constructed, an HBF type of control was developed for controlling

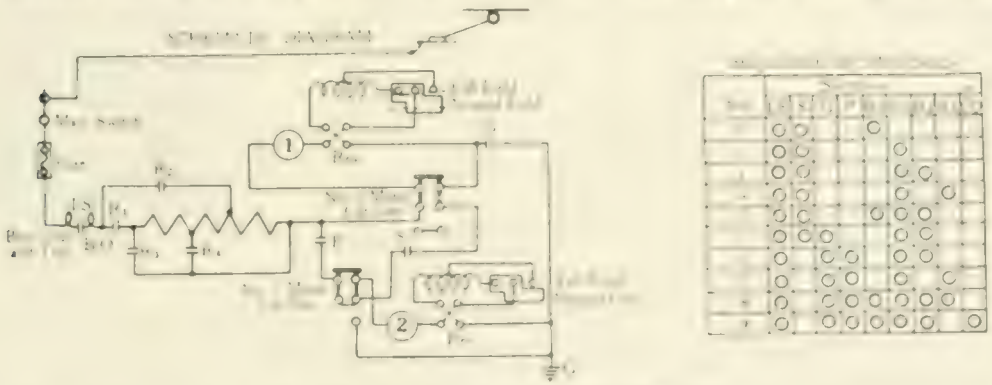


FIG. 10—DIAGRAM OF CONNECTIONS.

Two-motor equipment, with type HLF unit switch control similar to that shown in Fig. 3, but with the field control feature added.

the large 2000 hp commutating pole motors which propel them. The field of each motor is divided into two parts, and in both series and parallel running there are two running points: one with maximum or full field, and the other with normal or half field in circuit. In each case there are two transition positions between full field, and normal field. Thus these controllers have four the large 2000 hp, commutating pole motors which propel them. running positions. The handle of the master controller is arranged to have but a comparatively small amount of travel, similar to that of a steam locomotive throttle; however, by means of a gear connection, this small movement is multiplied in transmimssion to the controller drum.

An extremely quick-acting circuit-breaker is used. On ac-

count of its size it operates differently from the ordinary line switch or circuit-breaker, in that it can be tripped without first releasing the air from the main cylinder. By its quick action the extent of damage from short-circuits is greatly decreased. This main circuit-breaker is of high capacity and may be opened and closed by opening and closing the low voltage circuit which leads to the magnet valve that admits compressed air to the operating cylinder, or it may be opened automatically by means of a magnetic trip. The motor current passes through the coil of this tripping magnet and if the current through the circuit-breaker becomes higher than that for which the breaker is adjusted the plunger lifts and, striking against the trip, causes the breaker to

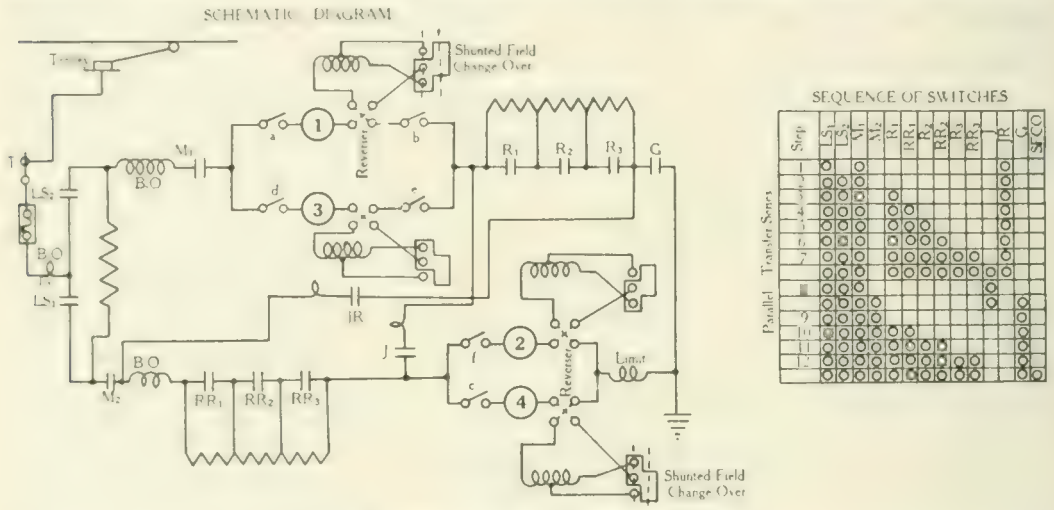


FIG. II—DIAGRAM OF CONNECTIONS.

Four-motor equipment, with type ALF unit switch control similar to that shown in Fig. 6, but with the field control feature added.

open. The movement of the main contacts when opening and closing is the same as in the unit switches. The operating mechanism is different, the moveable contact arm not being connected directly to the piston rod, but to the upper end of a guide rod operated by a vertical movement of this rod which is connected through a system of levers to the piston of the operating cylinder on one side and to the overload device on the other side, through a tripping lever.

These circuit-breakers are enclosed in iron cases. The arc chute in which the main contacts are contained is open so as to give plenty of room for the copper gases to vent when the breaker opens from excessive current. Powerful blow-out magnets are located on each side of the arc chute opposite the contacts. The circuit-breakers are located one on each locomotive unit, near the

cab partition adjacent to the switch groups, the arc chute venting toward the center passageway between switch groups.

As an emergency provision, in order to "kill" the third rail for any reason, a short circuiting or grounding switch is placed on each half of the locomotive. It is operated by a pull lever projecting through the floor on the left side of the cab. The closing of this switch unprotected by fuses causes a dead ground which is ample to trip the breakers at the sub-stations and thereby cut off power.

CONTROL SYSTEMS FOR 1200 AND 1500 VOLTS

Pneumatically-operated HL unit-switch control is peculiarly adapted for 1200 and 1500 volt operation. The following list of its inherent desirable properties indicates why this is so:—

1—The main contacts are held together with great and uniform pressure. Powerful springs open the contacts. Positive action is assured.

2—The magnetic blowout is exceptionally effective, due to the arrangement of the blowout coils.

3—The physical construction of the pneumatically operated switch permits the use of liberal insulation and surface creepage distance.

4—A low voltage, approximately 100 to 125 volts, is used across the magnet coils operating the magnet valves and interlocks.

When a pressure of 1200 volts is used on the trolley, the duty of the control apparatus is exceptionally severe, particularly when a breakdown takes place and the motors flash over; moreover, the resulting current is several times greater than that with 500 or 600 volts. Control equipment for 1200 volt operation must be designed to meet these conditions.

CARBON CIRCUIT BREAKER DEVELOPMENT

J. N. MAHONEY

IN THE early stages of electric railway development two forms of switchboard circuit breakers appeared as part of the general equipment. One type took the form of an overload trip switch having carbon arcing tips and known as the "carbon" circuit breaker. The other form consisted of an overload trip switch having arcing tips protected by a magnetic blowout. In the carbon form the tips on the stationary and moving elements engaged one another in parallel planes perpendicular to the supporting base of the apparatus, and had a sliding contact for a considerable distance which overlapped the engagement of the main copper contacts so that the copper contacts were disengaged before the carbons broke the circuit. This form of circuit breaker is illustrated in Fig. 1.

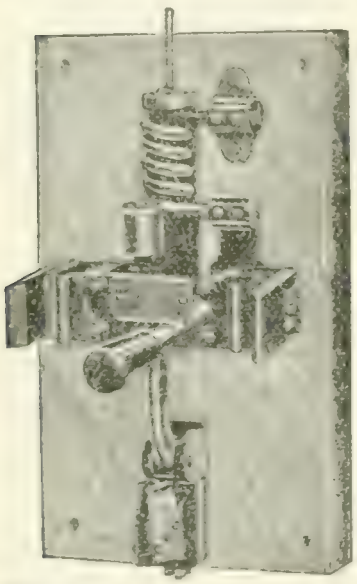


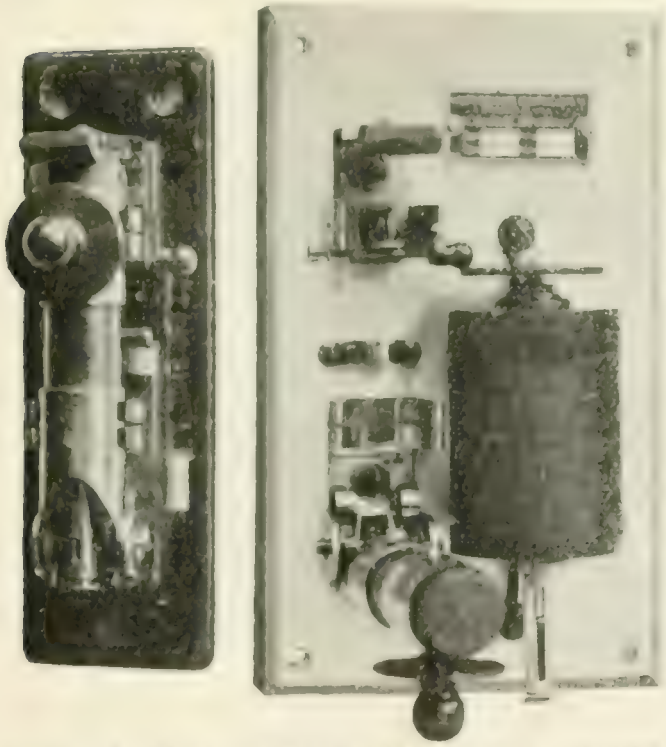
FIG. 1—EARLY TYPE OF CARBON CIRCUIT BREAKER

The earlier magnetic blowout switchboard circuit breakers had the blowout coils connected directly in series with the contacts, which construction was permissible while the generating plants were of small capacity. The heavier currents required in the larger installations—as railway development progressed—required a change in construction of magnetic blowout to a form in which auxiliary contacts or arcing tips were connected in series with blowout coils of relatively small conducting capacity, and this auxiliary blowout circuit was placed in shunt to the main contacts. The mechanical construction was such that the main contacts opened a short period before the auxiliary contacts in order to cut the magnetic blowout and arcing tips into circuit to take care of the arcing.

In the earlier forms of both types, the main contacts took the form of jaws and blades of generally similar construction to the present-day knife switch contacts. As the conducting capacity required was increased, it became necessary to obtain a more compact form for the main contacts, and the "laminated brush" or "bridge" form was developed. As capacities still further increased

it was found, in the magnetic blowout form, that the self-induction of the magnetic blowout circuit in shunt to the laminated bridge main contacts sometimes caused an arc to persist on the main contacts, under heavy short-circuit conditions, and destroyed them. This caused the abandonment of this form except in relatively small capacities.

The two prime functions of a circuit breaker are,—its ability to open the circuit with certainty under the abnormal conditions that cause it to operate, and its ability to conduct its rated current continuously, and abnormal current for short periods. It is evident from the preceding paragraph that the first function or "circuit breaking ability" was not successfully met by the magnetic blow-out type in large conducting capacities and all of the principal manufacturers have standardized on the carbon type of direct-current switchboard circuit breaker, in order to more fully meet the requirements of certainty of operation. The form of carbon arcing contacts, shown in Fig. 1, has also been abandoned for the forms illustrated in Figs. 4-12. It is possible for the form shown in Fig. 1 to roughen and lock the circuit breaker in its closed position. In the highest class of circuit breakers, all of the contacts are of the "butt" and "wiping" form under considerable pressure to afford large capacity per square inch of contact and good self-cleaning action in operation. The mechanism is also designed so that all of the mechanical forces applied to the several contacts shall assist in opening the circuit breaker.



FIGS. 2 AND 3.—TYPE OF CARBON CIRCUIT BREAKER FOR INDUSTRIAL USE, IN CAPACITIES UP TO 75 AMPERES, AT 250 VOLTS

The one at the left is plain overload front connected. The one at the right has both overload and reverse current trip and is rear connected.

Carbon circuit breakers are now made in sizes from 3 to 24 000 amperes capacity and for service up to 1 500 volts direct current.

The problems of design vary considerably with the circuit breaking ability and required conducting capacity. Where the capacity of the system is small and the conducting requirements of a particular circuit to be controlled are also small, a circuit breaker of the character shown in Fig. 2 will successfully meet the requirements. This particular form was developed to meet the demands of service ordinarily handled by enclosed fuses, where the overloads are liable to be so frequent as to make the cost of replacement of fuses excessive. This type is manufactured in capacities up to 75 amperes and 250 volts. It consists of a switch arm hinged at the bottom and composed of an insulating tube enclosing the overload



FIG. 4 — SINGLE-POLE CIRCUIT BREAKER

With plain overload, plain overvoltage, or plain shunt trip. Rear connected.

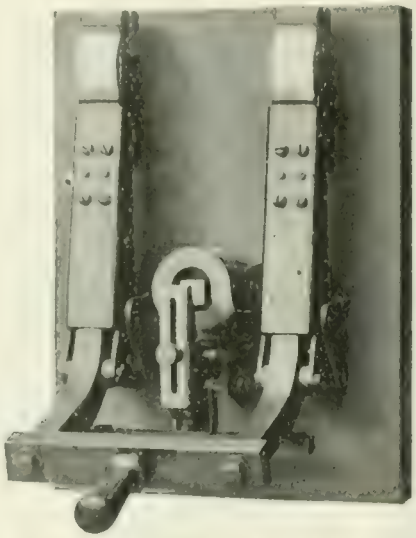


FIG. 5 — TWO-POLE CIRCUIT BREAKER

Double-pole single overload coil, without barriers, in capacities up to 400 amperes, 300 volt. Rear connected.

coil and having cylindrical metal portions at each end of the tube engaging with spring contacts. In the upper end of the tube is inserted a cylindrical carbon which wipes under a stationary carbon supported on a horizontal plane immediately above in such a manner that the contact on the carbons is not broken until after the main contacts have disengaged. This is a relatively simple device and very successfully meets the service for which it was designed. This type of breaker is shown in Fig. 3 with a reverse current trip mechanism in addition to the overload trip which is self-contained in the breaker mechanism. It is also built for operation on shunt trip and overvoltage as well as overload, to meet the various conditions required in practice.

In this type of circuit breaker there is but one step between the opening of the main contacts and opening of the circuit, namely, the insertion of the carbon arcing contacts, and therefore it is not adaptable where a very heavy current is to be broken on short-circuit. Because of the relatively high resistance of the circuit formed through these carbons, and the light conducting details used, an arc would probably form on the main contacts with injury to these parts and possible destruction of the circuit breaker. In order to meet the requirements of circuits and systems having somewhat greater capacity, a circuit breaker of the general design

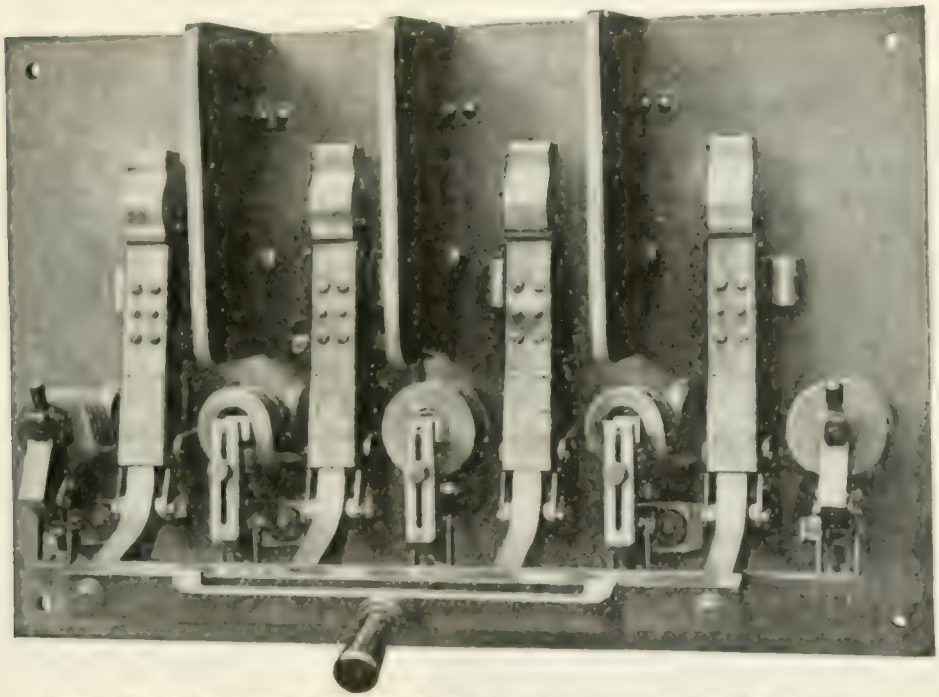


FIG. 6—FOUR-POLE SINGLE CLOSING HANDLE CIRCUIT BREAKER

With two overload, one underload, one undervoltage, one overvoltage, and shunt trip mechanism. Capacity, with barriers, up to 400 amperes, 750 volts. Front connected.

shown in Figs. 4, 5, 6 and 7 has been designed. In this form the main switch arm carries laminated brush-type contacts and also has a spring contact member bearing on the main contacts in addition to the brush. This is known as the secondary contact and it is arranged to remain in engagement after the laminated contact has broken the circuit, but it in turn interrupts its circuit before the carbon contacts have separated. This provides two steps of relatively increasing resistance in the progressive movement of opening the circuit, so that the liability of an arc forming on the main contacts is decreased further than where the carbon auxiliary contacts

only are used. Circuit breakers of this class are made in capacities up to 800 amperes.

Referring to Fig. 4, one of the specific characteristics is the particularly rugged construction secured by the use of punchings of wrought material throughout. This type of circuit breaker is designed primarily for small switchboards and industrial service up to 750 volts direct or alternating current. This figure shows a single-pole, plain overload trip, automatic breaker. A standard two-pole single arm (closing handle) circuit breaker with one overload coil is shown in Fig. 5.

One of the requirements of a line of automatic circuit breakers is that they shall be arranged so that they can be actuated by over-voltage, under-voltage, under-load, reverse current and shunt trip, in addition to plain overload, or any combination of these where required. In Fig. 6 is shown a four-pole circuit breaker actuated by overload coils in two of the lines, and in addition by under-load, over-voltage, under-voltage, and shunt trip. It also shows the use of barriers which are recommended where the voltage is above 300 volts. On the second pole, reading from left to right, shunt trip cutout contacts are shown which open the circuit of the shunt trip after it has performed its function of tripping the circuit breaker. These contacts can also be used to close and open circuits for indicating lamps, to show the operator at a distance whether the circuit breaker is open or closed.

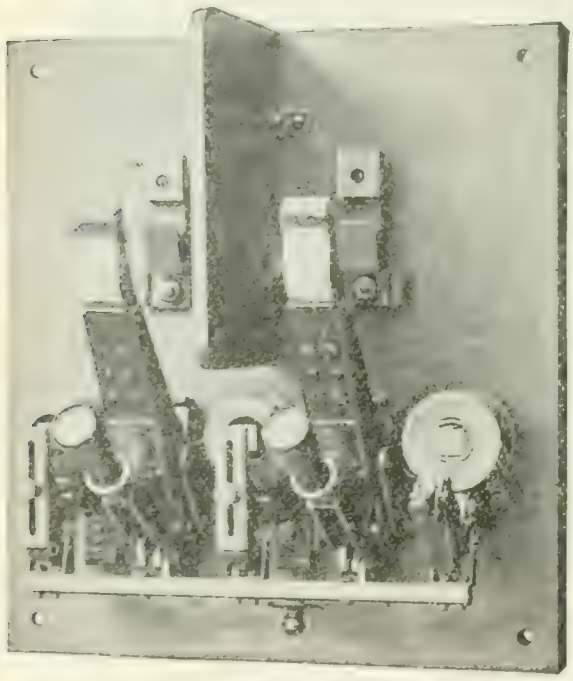


FIG. 7 DOUBLE-POLE DOUBLE-ARM COMMON TRIP CIRCUIT BREAKER

With two overload and one under-voltage trips. Capacity, with barriers, up to 400 amperes, 750 volts.

A two-pole "double arm," "common trip" breaker of this type with an overload coil in each line of the circuit and an under-voltage trip, is shown in Fig. 7. This type is particularly adapted to motor starting purposes on a 440 or 600 volt system having a grounded neutral, and dispenses with the use of a separate switch.

One pole can be closed at a time, and if a short-circuit exists, the first pole closed will trip when the operator closes the second pole. The under-voltage trip is for the purpose of disconnecting the motor from the line on cessation of voltage in the motor supply circuit. The usefulness of the overload coils in each line, in this instance, with a grounded neutral system is evident as a short-circuit could be produced from either line to ground. Either overload or under-voltage will trip both poles of the breaker through the common trip bar.

This type of circuit breaker may be supplied with a time element dash-pot on the overload mechanism to permit the passage of overload currents for a short period of time while starting motors.

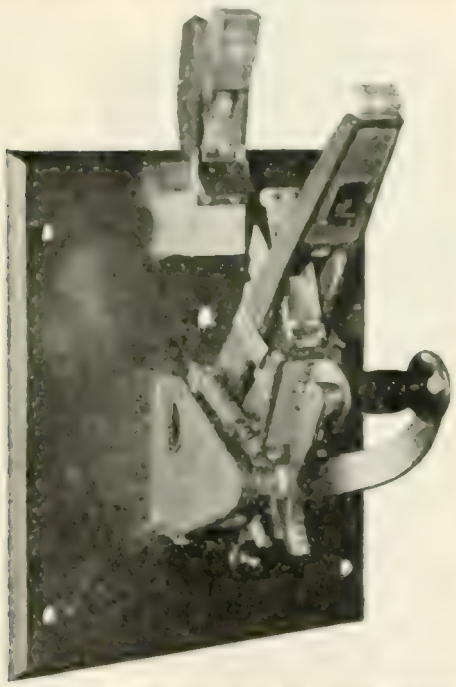
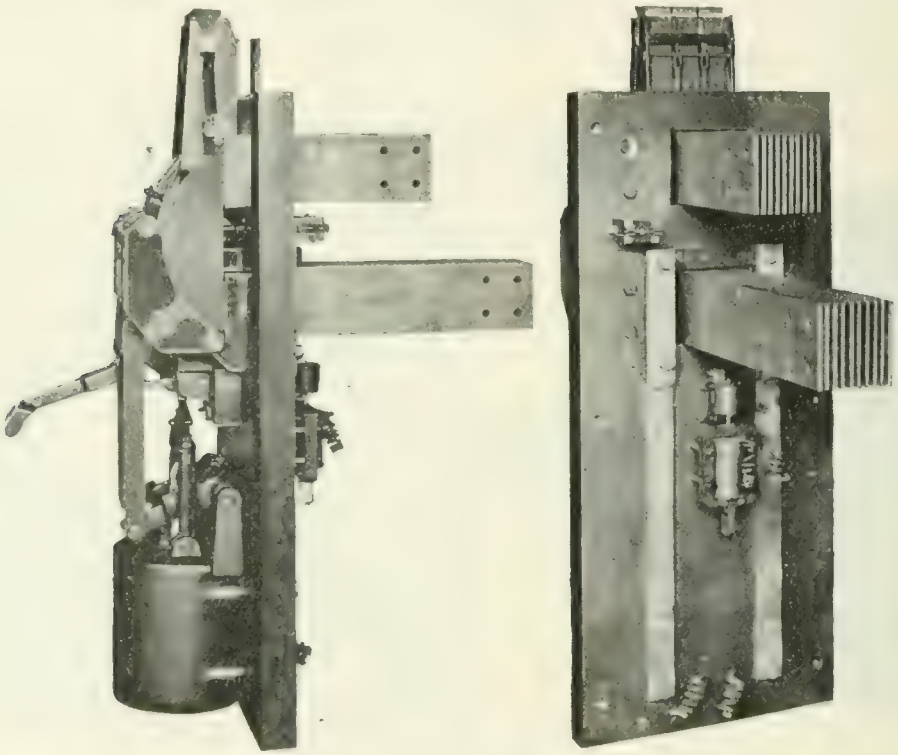


FIG. 8 — SINGLE-POLE, 200-2 000 AMPERE, 750 OR 1 500 VOLT CIRCUIT BREAKER
Actuated by overload and shunt trip.

It is evident from the above discussion that one of the main problems in circuit breaker design is to provide a circuit or number of circuits with increasing resistance in shunt to the main contacts to relieve them of the possibility of arcing. The final shunt circuit must also be capable of taking care of the arcing without excessive injury to itself. On modern heavy railway systems where from 30 000 to 60 000 amperes are obtained under short-circuit conditions, it is readily seen that one-thousandth of an ohm difference in the resistance of one of these shunt paths would cause a difference in potential of from 30 to 60 volts, which is sufficient to establish an arc. This requirement calls for several steps between the main contacts and the opening of the carbon arcing tips in circuit breakers of very high circuit breaking ability. This in turn requires a construction which will have dimensions and characteristics for controlling the value of resistance in the several shunt circuits. In the circuit breakers illustrated it will be noted that more or less of these features are included in accordance with the character of the service to be performed.

In Figs. 8, 9, 10, 11, 12 and 13 are illustrated several sizes and

forms of a line of circuit breakers having conducting capacities from 200 to 24 000 amperes, designed to meet the conditions of the heaviest service now known. By referring to Fig. 8, which illustrates the general form taken by this type in capacities from 200 to 2 000 amperes, the several steps in the progression of opening the circuit may be noted. In addition to the main brush contacts, a very substantial secondary contact is placed immediately above the brush and the details of this secondary contact are connected by substantial flexible shunts to the lower end of the tertiary contacts, which are substantial copper contacts, mounted on the same sup-



FIGS. 9 AND 10—SINGLE POLE, ELECTRICALLY OPERATED, 12 000 AMPERE, CIRCUIT BREAKER

With overload and undervoltage trip coils and laminated studs.

ports as the carbon arcing contacts. These contacts are so mounted as to be self-aligning in order to adapt themselves automatically to good contact relation with a similar set of contacts on the carbon arm of the moving element, and afford, at the same time, a wiping action to insure a good, self-cleaning contact. The carbon itself is heavily copper coated and machined at all points where it comes in contact with the tertiary contact and the conducting supports. All of these features are for the purpose of affording several steps in the opening of the circuit, each one of which will give a correct relation of the resistances of the several

successive shunt circuits up to the point of inserting the resistance of the carbon arcing contacts, which is relatively high. These features in themselves are quite distinctive from similar features in smaller circuits breakers that are not designed to meet such extreme conditions.

In addition to the constructional details above noted, the mechanism to accomplish the relative movement of these several contacts is more complex than in the smaller ones. By referring to Fig. 8 it may be seen that the carbon arm is actuated from the main brush arm by means of a spring connection. This construc-

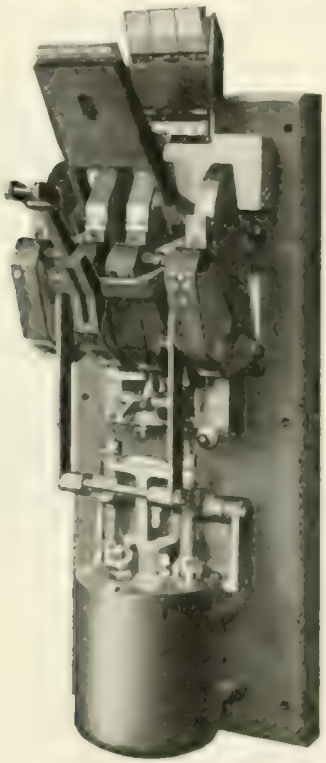


FIG. 11 — ELECTRICALLY OPERATED 12 000 AMPERE CIRCUIT BREAKER
Showing unit ventilated structure.

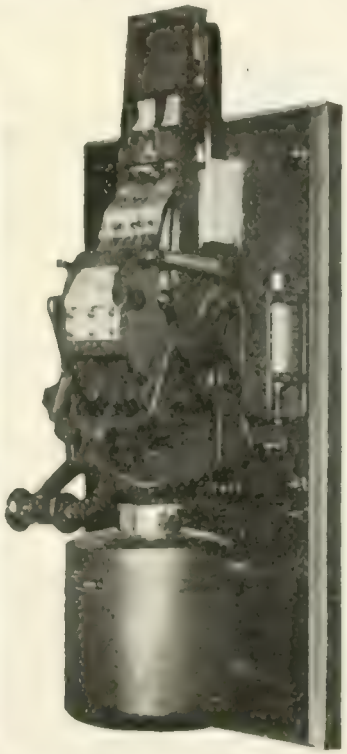


FIG. 12 — ELECTRICALLY OPERATED 7 000 AMPERE CIRCUIT BREAKER
Showing general type for 3 000 to 9 000 amperes capacity.

tion permits of a considerable movement of both the brush or main contacts and the secondary contacts, before any movement is caused at the tertiary contacts and carbon final contacts. The secondary contact is itself flexibly supported so that the main contact is broken before the secondary contacts have separated. A mechanical motion, before mentioned in connection with the carbon

and tertiary supports, provides the means by which the tertiary contact is broken in advance of the carbon final contacts.

The contact studs, which project through the panel, are in two forms, known as round or "solid" studs, and "laminated" studs. The round stud consists simply of a round bar of copper, integral with the contact head and threaded to receive the clamping nuts, passing through the switchboard panel. The laminated construction is particularly adaptable to alternating-current work and large capacity direct currents, and is illustrated in Figs. 9 and 10.

Figs. 9, 10 and 11 illustrate an electrically operated 12 000 ampere circuit breaker of this general type, and particularly show the method of utilizing conducting material most efficiently. This circuit breaker is composed of four 3 000 ampere units mounted side by side with considerable space provided between units for efficient ventilation and for reducing the skin effect when used on alternating-current work.

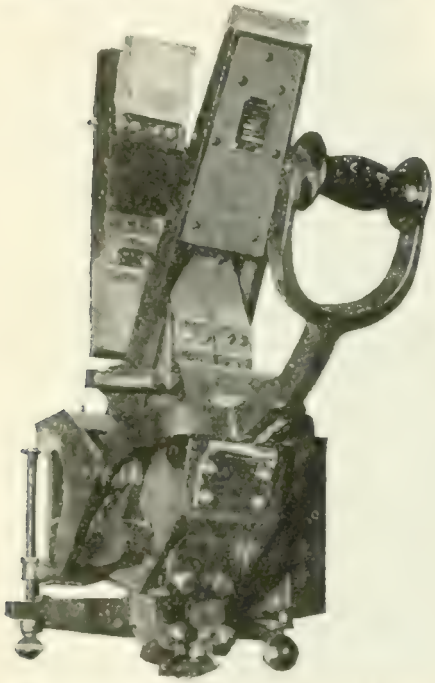


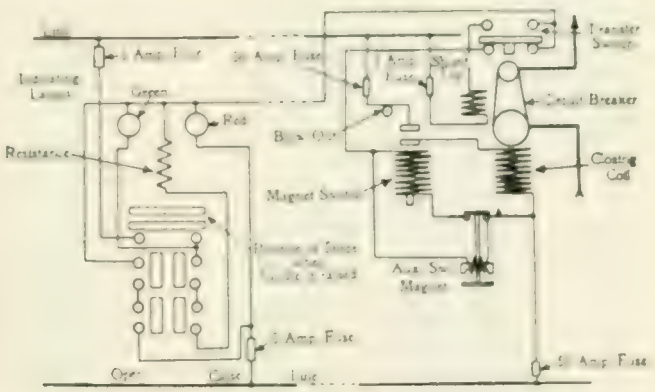
FIG. 13—4 500 AMPERE, HAND-OPERATED CIRCUIT BREAKER
Showing general type for 3 000 to 9 000 amperes capacity.

In Figs. 9 and 10 are illustrated particularly the laminated stud construction and the no voltage mechanism with which these breakers were equipped, in addition to overload. The similarity in design of the details of construction in this size to that shown in Fig. 8, of the lower capacities of the same type, will be noted. The particular ventilated form shown in Figs. 9, 10 and 11 is made in capacities from 10 000 to 24 000 amperes. In Fig. 12, which is a 7 000 ampere electrically operated, and Fig. 13, a 4 500 ampere hand-operated, circuit breaker, is illustrated the general form which this type of circuit breaker takes in capacities from 3 000 to 9 000 amperes, hand or electrically operated.

The rear view of a two-pole 7 000 ampere laminated stud, electrically operated, full automatic circuit breaker mounted on switchboard panel, is given in Fig. 14, which shows the relay switches for obtaining the full automatic features. The two small relay switches mounted just below the bus-bar and to the right of the

studs are mechanically actuated by the overload armatures of the circuit breakers, and in turn control the circuit of the magnetically operated switch shown in the center of the panel, which opens the circuit of the closing solenoid if an overload exists when the operator is closing the main circuit breaker. This feature makes it unnecessary to have separate switches in addition to the circuit breakers as, if thrown in on a short circuit by the operator, they will immediately trip and remain tripped until the operator returns his control handle to the off position and again closes the circuit. A diagram of the control connection involving this feature is shown in Fig. 15. This diagram shows that a circuit breaker of this type





FIGS. 14 AND 15.—REAR VIEW AND SCHEME OF CONNECTIONS OF TWO-POLE, 7 000 AMPERE REMOTE CONTROL MAGNET-OPERATED CIRCUIT BREAKER

Transfer switch operated by mechanism of the circuit breaker. Aux. sw. magnet, mechanically closed by the overload mechanism, and held closed by the magnet. The control switch has the positions, *open*, *off* and *closed*. The *off* is the normal neutral position to which the handle returns when released. The switch can be locked in the open position by raising the handle, which also cuts off all current from the contact circuit.

can be controlled, as to closing and tripping operation, by one wire, in addition to the local source of power supply, and that indicating lamps showing the position of the circuit breaker correctly, can also be operated over this same wire.

The electrically operated type, shown in Fig. 12, is closed by means of a solenoid mounted below the main mechanism. This solenoid is equipped with a dash-pot device to take care of the shock at the end of the closing operation and yet permit the circuit-breaker to be closed more quickly than is ordinarily possible with any other form of mechanism. When the closing switch is thrown,

current flows through the solenoid and the plunger is drawn down. This closes the contacts, which are held closed automatically by a latch. When the closing circuit is opened, the solenoid plunger is drawn up by a spring so that it will not retard the opening of the circuit breaker when tripped. The circuit breaker is opened by the overload trip or by a shunt trip attachment mounted at the side of the mechanism. A small plunger switch automatically opens the shunt trip circuit when the circuit breaker trips, and opens or closes the circuit of the signal lamps, if these are used.

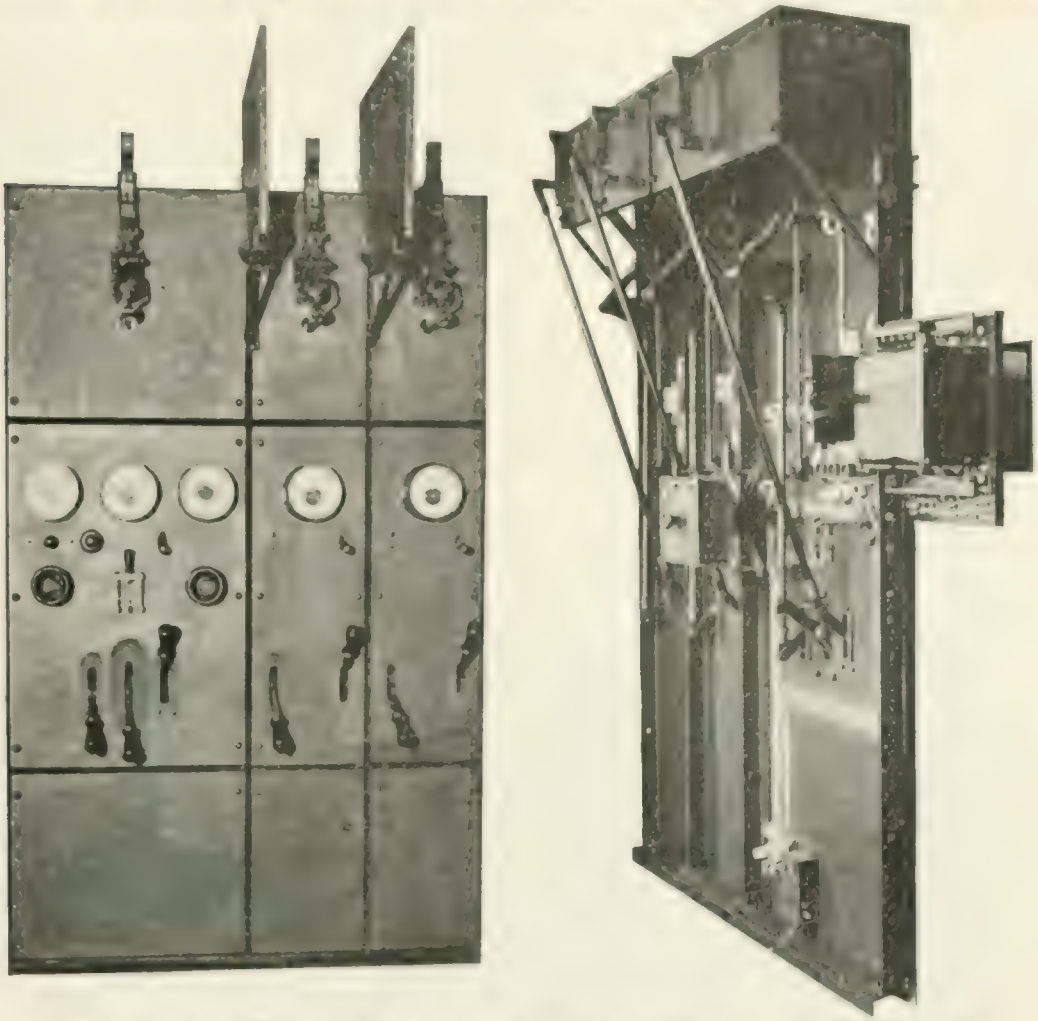


FIG. 16—REMOTE CONTROL. MOTOR OPERATED 4500 AMPERE COMBINED SWITCH AND CIRCUIT BREAKER

A motor operated form of combined switch and circuit breaker is shown in Fig. 16. This is a more expensive and complex form of remote operated switching mechanism than the solenoid form shown in Figs. 11 and 12, and is slower in operation, but requires much less current to operate. It is particularly adaptable to conditions wherein the control current is to be transmitted for long distances and where no local source of current supply for the solenoid form of breaker is available. The circuit breaking portion of this apparatus is the element connected to the operating rod on the left, the one on the right being the non-automatic or switch portion. It will be noted that although the switch element is not intended to be opened under load conditions, it is nevertheless provided with a secondary contact having a magnetic blow-out in the form of an iron yoke embracing the arc gap, and provided with an arc chute to take care of any arc that might take place. A full automatic feature is obtained in this motor operated form by reason of the fact that the switching element is not closed by the motor element until after the circuit breaker element has been closed and has become disengaged from the closing mechanism of the motor element. Under these conditions the circuit breaker portion can immediately trip when the switch element closes.

Figs. 17 and 18 illustrate the front and rear of switchboard

panels upon which 1 500 volt circuit breakers are mounted in connection with remote mechanical control means for closing and tripping them. Necessity for the special construction here indicated is evident by reason of the high voltage which these circuit



FIGS. 17 AND 18.—FRONT AND REAR VIEWS OF 1 500 VOLT SWITCHBOARD
With remote hand-operated circuit breakers.

breakers control. This makes it essential to place them high out of the reach of the operator and work them through rods having insulated sections between the operating handle and the circuit breaker.

SOUTHERN PACIFIC HIGH VOLTAGE DIRECT-CURRENT LOCOMOTIVES

SOME DESCRIPTIVE DETAILS OF THE NEW 600-1200 VOLT BALDWIN-WESTINGHOUSE LOCOMOTIVES FOR THE HARRIMAN LINES

G. H. F. HOLY

FIFTEEN sixty-ton, 600-1200 volt, direct-current electric locomotives are now under construction for the Southern Pacific properties. All of these, with the exception of one switcher, are for road freight service, but can be used for passenger service if required. In freight service a locomotive will haul an average trailing load of 600 tons and a maximum trailing load of 1200 tons. A continuous run of 100 miles is to be made in ten hours with ten stops of ten minutes each. This

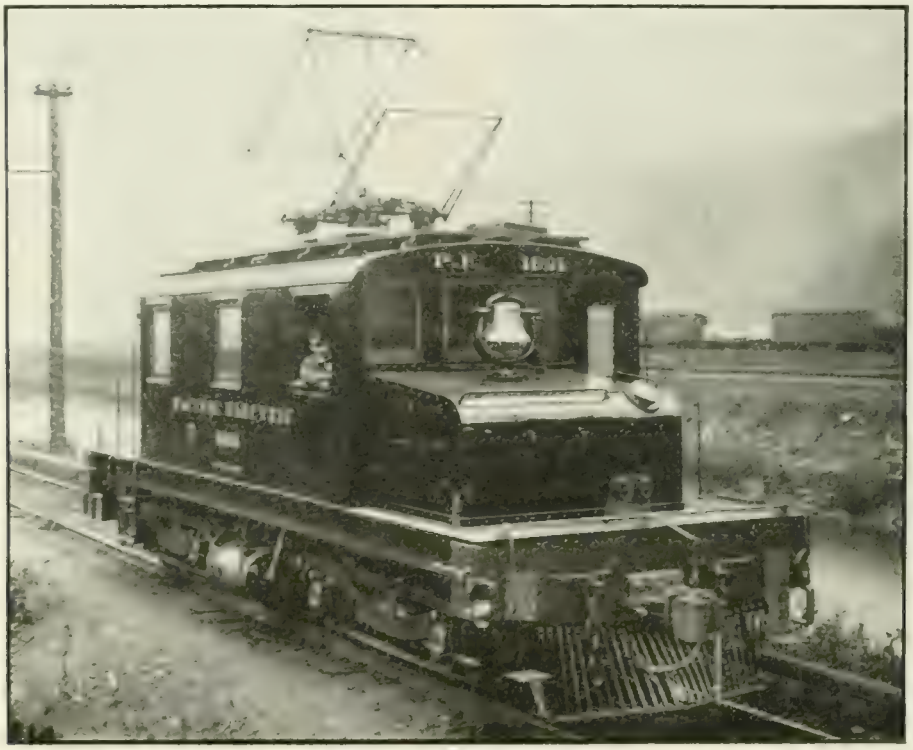


FIG. 1—ONE OF THE 15 SIXTY-TON, 600-1 200 VOLT, SOUTHERN PACIFIC DIRECT-CURRENT LOCOMOTIVES

run consists of a ruling grade of four percent for one mile, a two percent grade for one-half of the way and the balance at 0.5 percent, with grades in favor of and against the load. On the maximum grade the locomotives will be required to haul 300 tons. The maximum speed with average train on the level will be 25 m.p.h.

Power will be supplied from an overhead trolley, a form of catenary construction being used with the contact wire at a minimum height of 14 feet and a maximum of 22 feet. On the 600-volt sections, the voltage will range from 300 to 600 with an

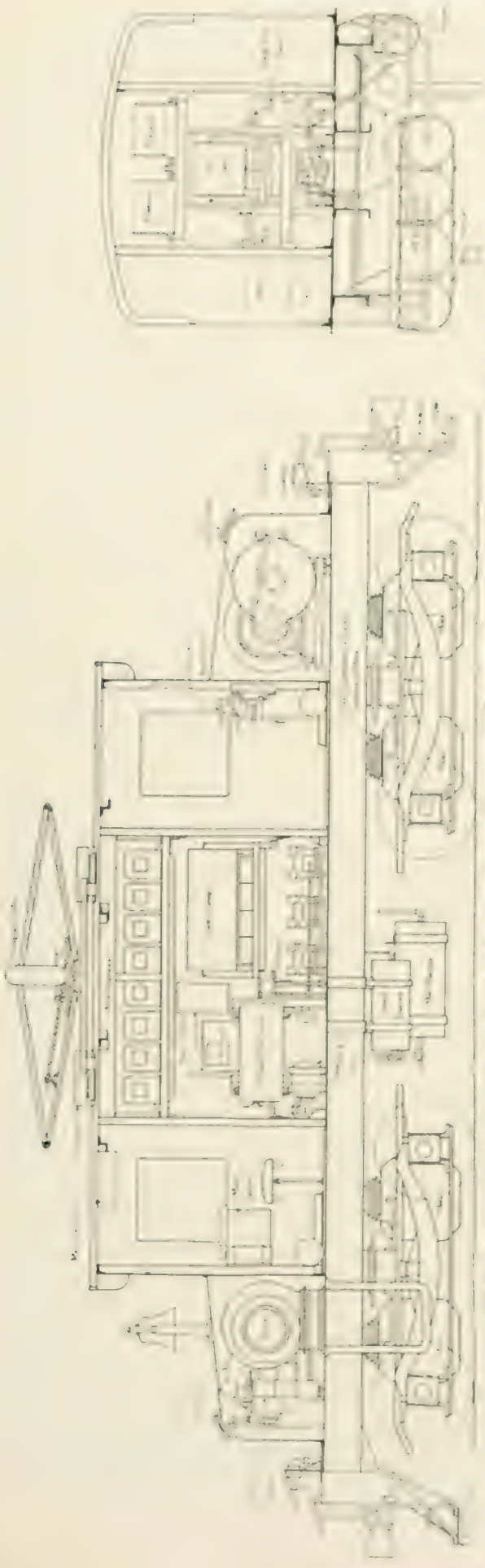


FIG. 2—LONGITUDINAL AND END ELEVATION OF 60 TON, 600-1 200 VOLT, DIRECT-CURRENT LOCOMOTIVE
Showing arrangement of equipment in main cab and hoods.

average of 500, and on the 1200-volt line the range will be from 900 to 1250 volts with an average of 1100 volts.

CONTROL

The type of unit switch used on these locomotives is that known as the HL type, in which acceleration is controlled by hand, and energy for operating the magnet valves is taken indirectly from the line. Most of the control equipment is mounted in the center of the main cab with an aisle on each side, and is surrounded by a grounded protecting screen of expanded metal. The main resistance grids are mounted next to the roof under the ventilators and directly above the switch groups, line switches and reversers, thus giving short runs for the wiring between the grids and apparatus, and direct disposal of heat from the grids. With this arrangement there is ample room and light for inspection, etc. The location of apparatus is indicated in Fig. 2.

Electro-pneumatically operated unit switch groups, shown in place in Fig. 2, are used for

making and breaking the main motor circuits. Each unit switch is provided with the usual effective magnetic blow-out peculiar to this type of switch for extinguishing the arc. There are 18 unit switches arranged in two groups of nine each. They serve to open and close the various connections between the trolley, motors, and resistance in proper sequence. Positive operation is a fundamental feature; the contacts are closed under a pressure of 150 pounds and opened under a counter-pressure of 125 pounds. These groups are controlled by a master controller at each end of the cab, operating on independent control circuits, power for which is furnished by a circuit tapped off of a 600-volt dynamotor circuit described below, by means of a suitable resistance. One of the master controller circuits, that to the control resistance, carries 600 volts; the remaining control circuits carry 200 volts or less. All wiring is carried in loricated iron conduit.

On 600 volts, three running speeds are obtained without control resistance in circuit, the lowest being with the four motors in series, the second with the motors in series-parallel, and the highest with all in parallel. On the master controller, there are nine accelerating notches and one running notch for series operation; while for series-parallel and parallel operation there are eight accelerating notches and one running notch. The sequence of operations is as follows:—The controller is notched up through first the series accelerating and running positions, and then through the series-parallel accelerating and running positions, with the two motors of each pair connected in series. To obtain suitable connections for multiple operation, the master controller has to be returned to the off position so that a series-parallel switch, described below, may be operated to connect the two motors of each pair in parallel, the locomotive being allowed to coast, momentarily, while this is done. The master controller is then swung through its ten "series" positions, which in reality gives series-multiple operation of the motors, and finally is carried through its "series-multiple" position, giving multiple operation of motors.

For 1200-volt operation, the series-parallel switch is prevented from being thrown to the parallel position by means of an interlock in its control circuit, so that the master controller is operative only for series and series-parallel connections of the motors. A line switch, shown in position in Fig. 2, is located in the main trolley circuit. It comprises four unit switches which act as a circuit breaker in connection with overload trips mounted on each side. These switches operate similarly to the motor control switch

groups. The overload trips are adjustable to open the main circuit at a predetermined overload. In addition to the line switches in the main circuit, a main fuse and knife switch are supplied.

The reversers are controlled by a separate lever on the master controller. They are pneumatically operated, thus allowing heavy pressure on the contact fingers and ample overload capacity.

A pneumatically operated series-parallel switch is provided to give series-parallel control on 1200 volts, and incidentally gives the multiple running position on 600 volts. It is operated by one of the control switches located at each end of the cab, within easy reach of the motorman. The control circuits are interlocked so that it is impossible to operate the series-parallel switch except when the main circuit is open. By means of a motor cut-out switch, either pair of motors may be disconnected from the circuit, in case of emergency.

In changing over from 600 to 1200 volts, a hand operated drum type switch is provided, as indicated in Fig. 2, to readjust the connections of the main grid resistances from parallel groups to series, and to connect the two dynamotors for either 600 or 1200 volt operation. The locomotives are also provided with train line receptacles and jumpers for multiple-unit operation of locomotives.

Other details of the control equipment include a two-position control switch which in one position serves to open the 600-volt control circuit from the master controller, thus making it and the switch groups inoperative, and when turned to the other position serves to reset the line switches; it is thus obviously impossible to reset the line switch without opening the control circuit. There is a dynamotor canopy switch for each of the two dynamotors. On closing this an automatic starting switch serves to short-circuit a starting resistance in series with the dynamotor circuit after a short time interval. Above each master controller there is an ammeter in addition to the air brake pressure gauges. An automatic overspeed relay is incorporated in the control equipment, whose function is to cut off the power in case a predetermined safe maximum speed is exceeded.

Current is collected by means of a pneumatically operated roller pantagraph trolley. A section break relay is also provided so that before the trolley passes a section break the line switches will be opened automatically in case the motorman fails to shut off the power, after which the master controller handle has to be returned to the first notch before the switches can be reset. This arrangement prevents destructive arcing at the section breaks.

The operation of the relay is controlled by an auxiliary circuit connected to two horizontal arms mounted on each side of the pantagraph trolley, parallel to the roller but several inches below it, and insulated from it. On the two bracket arms or span wires nearest to the section break, several "feelers," or contact brushes, are hung in a pendant position. These serve to make contact with the relay circuit through one of the auxiliary metal bars, and cause the relay to operate. A dash-pot prevents the relay from returning to its closed position for one or two seconds.

An electric warning signal is provided so that, with two locomotives double-heading, if the main circuit on the rear locomotive opens, a bell will be rung and advise the engineer of this fact.

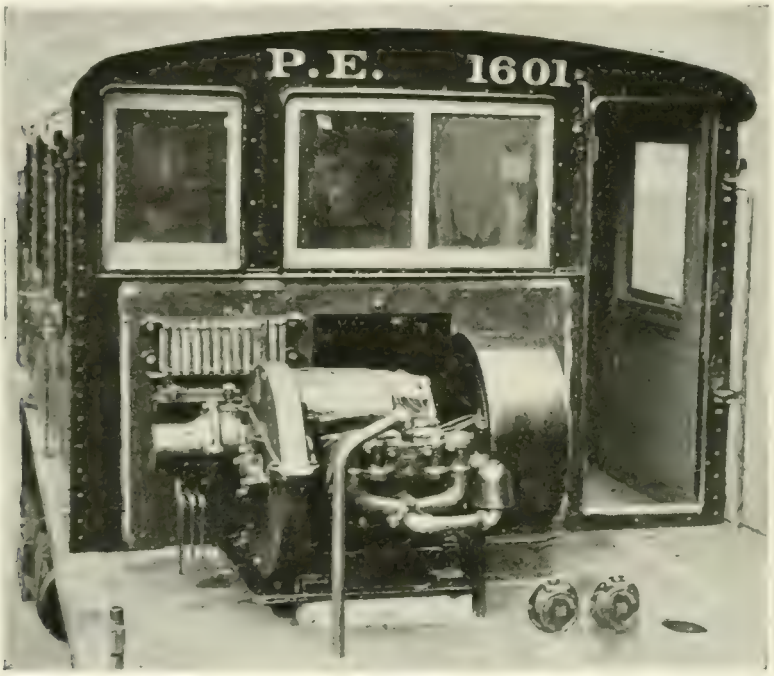


FIG. 3—END OF LOCOMOTIVE WITH HOOD REMOVED, SHOWING DYNAMOTOR-COMPRESSOR-BLOWER OUTFIT

The control and lighting circuits, the compressor for air brakes and control, and the blower for ventilation of the motors are all driven by this single unit. A duplicate equipment is located at the other end of the locomotive.

DYNAMOTOR-COMPRESSOR-BLOWERS

There are two dynamotor-compressor-blower sets, all combined into a single unit, which, with its necessary resistance, is mounted in one of the hoods as shown in Figs. 2 and 3. The dynamotors supply 600-volt power for the control circuit and for the lights in the main cab, hoods and headlights when operating on 1200 volts. Each dynamotor runs continuously on trolley voltage, either 600 or 1200 volts. There are two windings on the armature,

which are connected in series for operation on high voltage; a tap from the connection between the two supplies 600-volt power for the control and lights. When operating on 600 volts, these circuits and the 600-volt armature winding of the dynamotor, which is next to the ground, are connected directly to the line by means of the change-over switch. The compressor is automatically cut in and out at the required air pressures by means of a multiple-disc clutch, held in service by a steel spring and released by air from the main reservoir. The fan for the blower, mounted on the dynamotor shaft extension, supplies air for ventilating the motors.

MOTORS

Each locomotive is equipped with 4 four-pole, commutating pole, box type motors arranged for forced ventilation. One of these

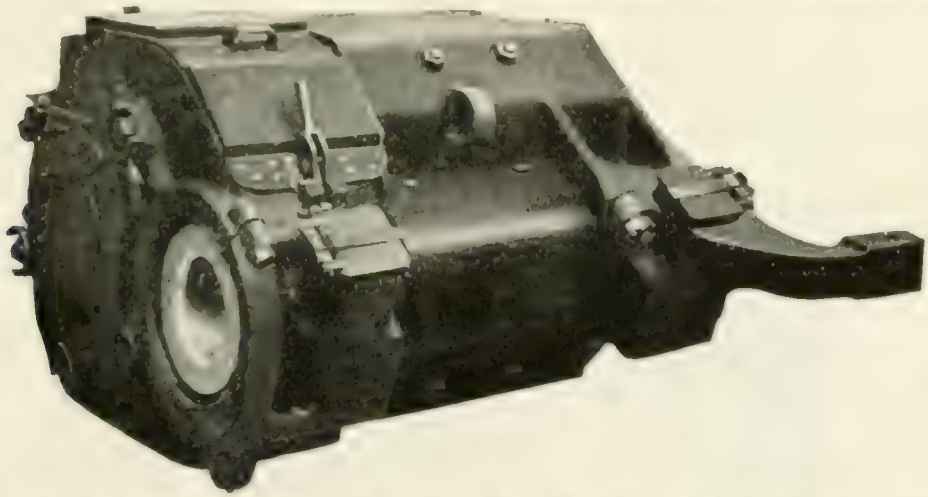


FIG. 4—ONE OF THE 600-1 200 VOLT MOTORS FOR SOUTHERN PACIFIC LOCOMOTIVES

is shown in Fig. 4. The nominal rating of this motor at 600 volts with forced ventilation is 250 horse-power. Each locomotive with natural ventilation of the motors can exert a continuous tractive effort of 5 600 pounds and with forced ventilation 11 520 pounds. The nominal one-hour rating of each locomotive, with natural ventilation, is 18 800 pounds tractive effort at 18 miles per hour on 600 volts and, with forced ventilation, 22 000 pounds tractive effort at 17 miles per hour. The maximum tractive effort of each locomotive with clean dry rails is 30 000 pounds.

The motor frame is of cast steel; the main poles are laminated, and the commutating poles are cast steel. The main field coils and commutating pole coils are strap wound. The armature core is of laminated steel built upon and keyed to a cast steel spider. The armature coils are of the formed, strap wound type. The armature has a maximum safe speed of 1 400 r.p.m. which is

equivalent to a locomotive speed of 42 miles per hour, with 36.5 inch wheels and a gear ratio of 16:57. The motors are adaptable to A.E.R.A. standard axles and standard mounting with one side carried on axle bearings and the other side carried by nose suspension on the truck bolster. Solid cast steel gears and heat treated forged steel pinions are used, and are enclosed in a malleable iron gear case. An interesting detail feature is the use of dust guards between the axle bearings, as shown in Fig. 5, a view of one of the trucks with motors mounted in position. Oil and waste lubrication is provided for both armature and axle bearings with a separate inspection well for gauging, and oil supply.

The commutator is built upon the cast steel spider of the armature core and is secured with bolts on the V-rings. The two brush

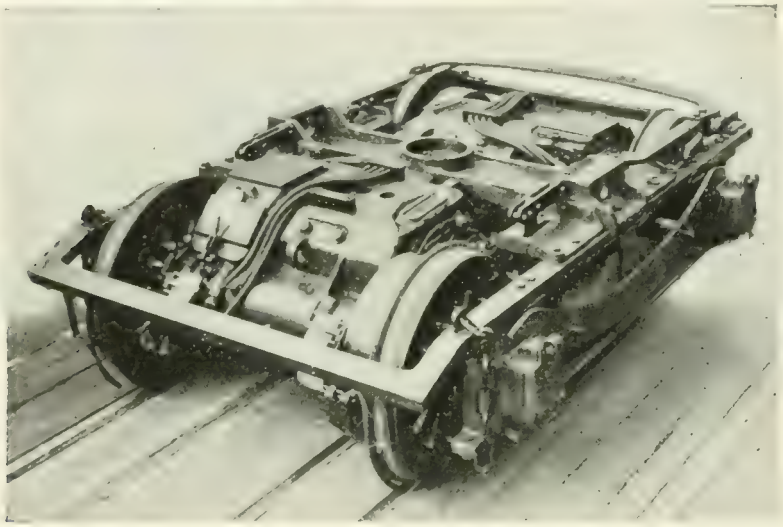


FIG. 5—GENERAL VIEW OF ONE OF THE TRUCKS, WITH MOTORS IN PLACE

The frame is a one piece forging, to which the cast steel bolster is secured. This bolster carries the cab frame by means of the center bearing. The side bearings serve to steady the cab.

holder arms are within easy inspection from above through the commutator opening in the motor frame, which permits also of quick brush replacements. The armature and axle bearings are of bronze, with a soldered lining of babbitt.

MECHANICAL PARTS

These locomotives are of the four wheel, double truck type, with central cab and sloping hoods at the ends. The draw-bar pull is transmitted through the cab under-framing and truck center pins. The cab under-framing consists of longitudinal center and side sills, four in all, of 13 inch rolled steel channel section, which are attached to heavy cast iron end frames or bumpers. On each

bumper is mounted a pocket casting for receiving a M.C.B. coupler. The center and side sills are strongly braced with transverse flanged plates, with one-half inch steel floor plates running the full length of the locomotive, and with the cab frame bolsters which consist of 1.5 inch plates, 15 inches wide, on which are mounted the center pins.

The main and end hoods of the cab are of steel, thoroughly braced and fastened. Doors are located at the ends of the main cab diagonally opposite and open onto a wide platform on one side of the hoods. All items of equipment in the cab can be taken out through the doors and windows. The hoods may also be easily and quickly removed for overhauling the equipment.

The trucks are of the rigid bolster, equalized pedestal type with semi-elliptic driving springs. The pedestals are provided with wearing gibs. The bolster is of cast steel securely fastened with reamed tapered bolts to the truck frame, which is a one-piece steel forging. The driver journal boxes are M.C.B. standard of the Symington type with dust-proof guards. The wheels have cast steel centers with rolled steel tires secured by bolts. The brakes are inside hung.

The weight of the electrical apparatus including the brake equipment is approximately 45 000 pounds, and the weight of mechanical parts including the brake rigging 75 000 pounds.

The principal dimensions are as follows:—

Gauge of track	4 feet, 8½ inches.
Diameter of driving wheels	36½ inches.
Axle journals	5½ by 10 inches.
Rigid wheel base	7 feet, 4 inches.
Adaptable when running slowly without trailing load for a curve with radius of	40 feet.
Total wheel base	25 feet.
Truck center distance	17 feet, 8 inches.
Height from top of rail to center of draw bar	2 feet, 9½ inches.
Distance between coupler knuckles	35 feet.
Total width (over steps, grab rails, gutters, etc.)	10 feet.
Height from top of rail to top of cab	11 feet, 5½ inches.

AIR BRAKE EQUIPMENT

A standard form of electric locomotive air brake equipment, known as the No. 14 EL, is supplied, and in addition a hand brake is provided for holding the locomotive when out of service. With this air brake equipment the locomotive brakes may be used with or independently of the automatic train brakes.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

778—**Operation of an Armature with Damaged Coil**—A 220 volt, 4 pole direct-current motor was equipped with a variable speed drum controller, and used to drive an emery wheel and a grind-stone. The linings of the bearings were of iron. The circuit breaker opened and smoke rose from the machine. Examination showed that the insulation was entirely burned off of one armature coil. The entire machine was very hot. The belt was removed, and the armature found to turn freely. The circuit-breaker was closed and the controller moved to the first point, but the armature did not turn. On moving to the second point, the circuit-breaker opened. The breaker was again closed and an attempt made to turn the armature, but it stuck as though rubbing on the pole-faces or binding in the bearings. The armature was removed and the laminations and those of the pole pieces were seen to be rubbed bright. As there was less than one-thirty-second of an inch looseness in the bearings the armature was placed in a lathe, and found to be centered. The field was then placed in a lathe, and the rubbed pole-faces found to be a little long. These were turned off. The burned armature coil was disconnected from the commutator and the open bars connected to adjacent bars by jumpers. The machine was then reassembled, and while the armature turned freely so long as the field was not excited, as soon as the breaker was closed it was almost impossible to turn it by hand. The brushes were raised from the commutator, but this had no effect. The armature did not touch the pole-faces at any point. A similar armature taken from a spare machine and exchanged for the burnt one ran nicely. The burnt armature was placed in the frame of the spare machine and behaved as before, refusing to turn when the field was excited and opening the circuit-breaker when the controller was moved to the second point. No movement whatever could be observed in the armature or bearing on opening and closing the breaker. Raising the brushes from the armature had no effect. The armature offered as much resistance to moving when at a standstill as it did after commencing to move. The armature shaft seemed to be firm and tight in the spider. One end of the armature shaft showed slight traces of magnetism when the field was excited, but the satisfactory operation of the second armature proved the field coils to be all right. Please explain. M.H V.

In the first place the armature has a burned out coil due to a short-circuit. The insulation being burned off this coil it has probably become grounded on the core. It is also probable that one side of the line is grounded so that for certain positions of the armature the grounded coil causes a dead short-circuit on the line which causes the circuit-breaker to open. In attempting to start the motor with the damaged armature there is enough resistance in the controller on the first notch to keep the current below the value at which the breaker is set, but on the second notch the current is too high for the breaker and it is therefore opened. The armature does not start because the current flows to the damaged coil, to ground and back to the other side of the line, without going through the remaining coils which normally would cause the armature to rotate. In cutting out the damaged coil it appears that other coils have been short-circuited by

consecutive bars. Assuming that this is a two-circuit progressive winding; in order to put the armature in temporary running condition, without rewinding, by cutting out the damaged coil, it will also be necessary to cut out its mate on the opposite side of the armature. For instance, if the armature has a commutator with 97 bars, the throw of the leads on the commutator will be 1 and 50, and on the opposite side of the armature there will be a coil connected to bars 50 and 2. If coil 1 and 50 is the burned out and grounded coil, it should be entirely disconnected from the commutator. Since coil 50 and 2 completed the connections to bar 2 this is now a dead coil, and if in good condition need not be disconnected. The condition of the armature now is: an open-circuit between bars 1 and 2 and bar 50 dead. It is now necessary to connect bars 1 and 2 and to make bar 50 alive by connecting either to bar 49 or 51. The armature may now be put in service but will run slightly higher in speed than before. The cause of the armature turning so hard with field on and with the brushes up must be some mechanical reason, probably end thrust, the armature being pulled against the bearing shoulder or made to rub on the housing by the core not being exactly in the center of the field. F.A.R.

779—Speed Characteristics of Reversible Interpole Motor—In the case of an interpole motor on a 1 to 1 traction elevator, A says that when the car is ascending light and the counterweight is dropping that the armature will generate a current in the opposite direction to the applied e.m.f. and reverse the interpole coils which in turn weakens the fields to such an extent that the motor will run away. B says that it is impossible to generate a current without reversing the shunt field. Is either party right? Why does the ammeter read backward when placed on an elevator motor line and the counterweight is descending? J.E.Y.

A is correct in that the motor, if driven above speed at which its counter e.m.f. equals line e.m.f., will act as generator, the current flowing in armature and interpole coils in a reverse direction from that as a motor. In a shunt motor, with proper auxiliary pole strength, and exact setting of brushes on neutral, the auxiliary poles should have no appreciable effect on racing. The braking action of generator current pumping back into the line would tend to prevent racing. The amount of overspeed required before effective braking is obtained would vary somewhat with the design of motor. This reversal of current explains the action of the ammeter which was noted. The operation of the motor may be explained more in detail as follows: In general, any shunt motor, if driven above the speed at which the counter-e.m.f. generated in its armature exceeds the e.m.f. impressed upon the armature, becomes a generator feeding power back into the line. The current in the armature and, therefore, the torque, reverses in direction; the latter resisting the driving torque and tending to prevent excessive speed. If the motor is equipped with interpoles, the current in the interpole windings, and hence the interpole magnetization, is reversed in direction as is necessary on account of the reversal of magnetic polarity of the armature and the necessity of commutating a flux of opposite polarity from that required when the machine is operating as a motor. The weakening of the main flux through saturation, due to the presence of interpole flux, will not be greater as a generator than as a motor and it should not be excessive in any event. In the case of "over-commutation," i.e., where the interpole excitation is slightly stronger than required, circulating (short-circuit) current in the armature coils undergoing commutation would tend to strengthen the main field in a generator and, therefore, cause the braking action; in case of "under-compensation," the short-circuit current would tend to weaken the main field. If the brushes are not accurately set on neutral, the main field will be strengthened if the setting of brushes is behind neutral, or weakened if in advance of neutral. In a compound motor, before generator action will result the speed must rise considerably higher than in a

shunt motor, because of decreasing strength of field magnetism; when operating as a generator the current in the series field coils is reversed and hence the braking action increases much less rapidly with rise in speed due to the differential action between the shunt and series fields. In such a case, there might be danger of racing, particularly if the motor is strongly compounded. A.C.L.

780—Method of Reducing Skin Effect in Heavy Current Transformers—How are the conductors arranged in making the low-tension coils for large three-phase or single-phase core type transformers carrying heavy currents, so that trouble due to eddy currents in the copper strips is avoided, still maintaining a neat mechanical arrangement. My understanding is that it is necessary to change the inner and outer conductors half way down the core in order to reduce the eddy current loss. Will you please give details of arrangement? S.C.

The load losses in such a transformer will include both eddy currents and circulating currents. The eddy currents can be reduced by using a large number of insulated wires in parallel so that the cross-section of each individual conductor will be small. Circulating currents are due to different conductors in parallel being in leakage fields of different strengths which set up different voltages and cause a current to flow around among the conductors, the effect being similar, on a small scale, to that produced by short-circuited turns. This can be overcome to a large extent by crossing and interchanging the positions of the wires that are in parallel so that the voltage set up by the leakage flux will be practically the same in all wires. This crossing is often difficult to make and is not easy to explain without reference to an actual transformer. W.M.M.

781—Testing Three-Phase Transformers—In testing for copper loss, and impedance voltage on a three-phase transformer, either core or shell type, by means of single-phase current, what modifications would be necessary in order to apply the formula for regulation as used for single-phase units? S.C.

In testing a three-phase transformer for copper loss and impedance the measurements can be made conveniently by connecting both the high-tension and the low-tension windings in delta and opening up one corner of one delta and inserting a wattmeter, voltmeter and ammeter, and impressing sufficient single-phase voltage across this corner at the proper frequency to cause normal full load current to flow through the windings. The wattmeter reading gives the copper loss and this divided by the normal full load input to the transformer is the percentage copper drop. One-third of the voltage measured on the voltmeter divided by the normal voltage of the winding of one phase in the percentage impedance drop. In a three-phase winding designed for delta connection the normal voltage of the winding of one phase is the line voltage while if the three-phase winding is designed for star-connection, the normal voltage of the winding of one phase is the line voltage divided by $\sqrt{3}$. With these values the regulation of a three-phase transformer is worked out in the same manner as for a single-phase transformer.

W.M.M.

782—Reconnection of Two-phase Induction Motor for Three-phase Operation—How is it that changing the number of poles on an induction motor will allow it to be worked on a different voltage? For example a two-phase, 60 cycle, 220 volt, 10 pole motor was changed to a three-phase, 60 cycle, 550 volt, 12 pole machine and gave satisfactory operation. Could it have been operated on 550 volts while still connected as a two-phase machine if the connection had been changed to give a larger number of poles?

W.H.L.

Had the motor been connected for 550 volts, three phase, ten poles, the operation would have been approximately the same as for the original motor connected for 440 volts, two-phase, ten poles, ie., the series connection corresponding to 220 volts, two-phase, ten poles.

When connected for 12 poles, three-phase, and run at 550 volts, the operation is approximately the same as for 440 volts, two phase, 12 poles. This would be practically the equivalent of operating the 440 volt, two-phase, 10 pole motor at an increase of voltage of 20 percent. Such operation may or may not be satisfactory depending on how liberally the motor is designed. If the motor is connected for 12 poles, two-phase and operated on 550 volts it will give approximately the same performance as the 10 pole motor operated at an increase of voltage of 50 percent, which would be excessive. It may be said in general that satisfactory operation cannot be obtained by reconnecting for a different number of poles, to give change of speed. When such change is desired the safest measure is to refer the matter to the manufacturers of the apparatus giving all available information regarding motor rating and various identifying data as well as information regarding the operating requirements of the application. M.W.B.

783—Proposed Single-Phase Railway with Power Regeneration—I am preparing a general scheme for an electric railway in which I propose to use single-phase power at about 11 000 volts and 15 cycles. The line will be approximately 194 miles long with four hydro-electric generating stations at A—37 miles, B—88 miles, C—131 miles, and D—162 miles. About half way between *B* and *C*, at 110 miles, is a summit, and for about 10 miles on each approach to this summit the line rises with a heavy gradient. I wish to have the locomotives arranged to return current to the line when descending. What I wish to ask, is, when one or more trains are ascending a steep grade towards the summit, say from *B*, and there is no train ascending from *C*, can current from *C* be utilized in helping *B* to carry trains towards the summit on the steep grade; *i. e.*, can current from trains descending towards *C* be utilized on *B's* section and vice versa? The affirmative will make a considerable reduction in power required at *B* and *C*. J.H.

Single-phase locomotives can be arranged to return power to the line. If the trolleys or generating systems are continuous between *B* and *C*, the energy derived from trains descending from the summit towards *C* can be used to assist the trains ascending from *B* towards the summit. On heavy grade work of this nature regeneration at a single speed is sufficient. Apparently the heavy grade section on either side of the summit would require pusher service. In this case three-phase pushers might be adaptable, as three-phase locomotives will return energy to the line automatically on down grades without any additional apparatus. F.E.W.

784—Steel vs. Brass Extension Rod in Plunger Magnet—Consider a plunger type solenoid with 1 7/16 inch cold rolled steel plunger, and 2½ inch air gap. The moveable plunger is arranged to give a "thrust" by means of an extension rod through a hole in the stop. This extension rod is made of brass. What effect will it have on the power of the magnet to make this extension rod of steel. S.L.H.

At maximum air gap (in this case 2½ inches) the power of the magnet will be *decreased* in proportion to the amount of flux which is carried by the small steel rod. This is readily understood by imagining the steel rod to be equal in diameter to the core, at which point the pull would be zero. At zero air gap the effect of the one-half inch steel rod would be practically nil. N.O.I

785—Brass Shields on Rotary Converter—Why does the older type of rotary converter have a brass shield over the armature winding at the alternating-current end? I understand why any material put on as this is, should be made of brass. Is it put on to prevent a flaring out of the winding in case of an overspeed, for instance, when running as an "inverted rotary"? J.D.S

A dropped involute type of coil was used and the brass bell was employed to prevent axial and radial movement due to centrifugal force. There was no special provision for inverted operation more than for normal operation. J.L.Y

786—Operation of Bearing Under Water—(a) In a case where a water turbine bearing can be run either under water or simply with intermittent oiling, considering the chance for the bearing being neglected, which would be the safer method of lubrication? (b) How does the coefficient of friction of a babbited bearing with water as a lubricant compare with one using oil as a lubricant, assuming the oiling to be intermittent? The bearing under consideration is so located with reference to the belt drive that it is difficult to oil. D.R.

(a) If the bearing in question is a guide bearing, not a thrust bearing, it would be preferable to run it under water, using a bronze sleeve on the shaft and lignum vitæ liners in the bearing. A.K.

(b) Assuming the bearing to be built without special care, but with ordinary good workmanship, the friction would be less with water if the load be small and the speed high; but if the load be high and the speed low, oil would give the lower friction. A.K.

787—Starting Induction Motors in Factory by Gradually Raising Voltage—In an industrial power plant where there are a number of motors driving machines, all of which operate together, each passing its material along to the next, forming a continuous process, is it practical to use squirrel-cage motors for the individual units and start them together from the power plant by gradually raising the voltage, full-load torque being required on all the machines? Can you give instances of operation in this manner? M.O.S.

Such a thing might be theoretically possible and may be practical, although we know of no place where it is being done. If it were attempted it would be better to bring up the generator from rest, directly connected to the motors and with full field on. In this way the frequency and voltage would build up together and it should be possible to start up satisfactorily in this way. A.M.D.

788—V-Connection of Transformers of Different Make—Is it possible to connect two transformers of different make in V or open delta connection, say, for example, the Westinghouse and G. E. or a Westinghouse and Pittsburgh, etc.? If not, why; and if so, what details regarding arrangement must be observed? K.A.K.

The inherent design characteristic, especially with regard to regulation of the various standard makes of transformers are so nearly identical that, for all practical purposes, there would be no restrictions as to the use of two transformers of different make connected in V, provided that the transformers are of like capacity, unless they are to be operated in multiple with other V-connected groups of transformers. For parallel operation, the same precautions should be taken as for multiple operation on any transformers. Note the following articles bearing on this phase of the subject. "Operation of Delta and V-Connected Transformers in Parallel," by Mr. E. C. Stone, April, 1910, p. 304; "Determination of Polarity of Transformers for Parallel Operation," by Mr. Wm. McConahey, July 1912, p. 613. C.F.

789—Heating of Iron Screws in Reactance Coil Apparatus—A reactance coil is being used on a mercury rectifier circuit for which the normal voltage is 220 volts direct-current, but which is working on 330 volts direct-current. As constructed, this apparatus has a sheet iron plate fastened to the iron frame by means of three screws. After one or two minutes of operation, the center screw gets very hot, in fact, too hot to touch. If the middle screw is removed, the upper screw becomes hot, and if this is removed the lower screw becomes hot. At the same time the coil becomes very hot and shows danger of burning out. Please explain cause and remedy. R.B.A.

There is evidently strong alternating-current flux passing through these screws, and as they are solid, there is a large eddy current loss in them. It is likely that if brass screws were substituted for the iron ones, the flux would not be concentrated in them and they would not get hot. It may be that the iron plate also becomes hot in the same way. If so, it would be advisable to substitute a sheet brass plate. R.P.J.

ANNUAL CONVENTION OF THE AMERICAN ELECTRIC RAILWAY ASSOCIATION.

The thirty-first annual convention of the American Electric Railway Association will be held in Chicago, October 7-11th. Sessions of the Association will be held in the Saddle and Sirloin Clubhouse, which adjoins the exhibit hall and is convenient to the Stock Yards Inn.

The principal items in the program of the Engineering Association are:

Monday, 2:30 P. M.—Reports and appointments of committees.

Tuesday, 9:30-11 A. M.—Reports of Committees on Block Signals and on Train Operation.

Wednesday, 9:30 A. M.-1:30 P. M.—Reports of Committee on Buildings and Structure; Report of Committee on Standards; Report of Committee on Power Generation.

Thursday, 9:30 A. M.-1:30 P. M.—Report of Committee on Engineering Accounting; Report of Committee on Railway Physical Property; Report of Committee on Way Matters.

Friday, 9:30 A. M.-1:30 P. M.—Report of Committee on Heavy Electric Traction; Report of Committee on Equipment; General Business, Nominations, Elections, etc.

The principal items in the American Association program are:

Tuesday, 2-5 P. M.—Annual address of president; reports of committees; address, "The Future of the Interurban," by Mr. Randal Morgan; address, "Water Power Development and its Relation to Public Utilities," by an H. M. Byllesby representative.

Wednesday, 2-5 P. M.—Reports of Committees; address, "Public Policy," by Mr. Arthur Warren; address, "Arbitration in Australia," by Mr. J. S. Badger, of Brisbane, Queensland, Australia; address, "The Milwaukee Fare Case," by Mr. R. B. Stearns.

Thursday, 2-5 P. M.—Reports of Committees; address, "Electric Railway Securities," by Mr. Morrell W. Gaines; address, "Automatic Rate Regulation," by Mr. O .T. Crosby; election of officers and unfinished business.

The convention exhibition is to be in the International Amphitheater. It is reported that all the exhibit space has been engaged. The addition to the general exhibit of twelve cars and two repair cars, and a train of sixteen cars, for the track display, will make the Chicago exhibit the largest ever shown.

PERSONALS.

Mr. N. A. Carle has been appointed chief engineer of the Public Service Corporation of New Jersey, with headquarters at Newark.

Mr. W. F. Fowler, manager of the Pittsburgh district office of the Westinghouse Electric & Mfg. Company, has resigned to accept a position with the inteersts controlled by Messrs. J. S & W. S. Kuhn, Pittsburgh, Pa.

Mr. H. C. Specht, the well-known designing engineer, who for the past nine years has been connected with the engineering department of the Westinghouse Electric & Mfg. Company, has resigned his position for an indefinite period on account of private interests in Germany. Mr. Specht has gone abroad and will take charge of construction work in connection with some large textile mill projects for the Norddeutsche Wollkæmmerei und Kammgarn-Spinnerei at Delmenhorst, near Bremen.

Mr. W. B. Underwood, for several years head of the electric heating apparatus division of the Detail & Supply Sales Department of the Westinghouse Electric & Mfg. Company, at East Pittsburgh, Pa., has taken a position with the American Sterilizer Company, Erie, Pa., to be engaged in sales and engineering work.

Mr. J. MacArthur Duncan, director of works accounting at the East Pittsburgh works of the Westinghouse Electric & Mfg. Company, has been appointed manager of the Pittsburgh district office, succeeding Mr. W. F. Fowler, resigned.

Mr. T. L. Schrantz, of the Buffalo district office of the Westinghouse Electric & Mfg. Company, has been appointed manager of the Syracuse branch office.

The *Electrical Review & Western Electrician* for August 31st, contains a reprint, from the August issue of the JOURNAL, of the article by Mr. H. M. Scheibe, on "The Selection of an Electric Fan."

The *Practical Engineer* for September 15th, contains the article by Messrs. Lyford and Stovel, entitled "Steam Electric Power Plants," which was published in the JOURNAL for April.

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PERSONALS.

Mr. R. J. Dearborn, of the patent department of the Westinghouse Electric & Mfg. Company, East Pittsburgh, has resigned to become associated with Mr. E. W. Marshall, counsellor-at-law and patent expert, with offices at 76 William street, New York City.

Mr. F. G. Clark, superintendent of power plant for the Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa., resigned August 15th, to accept the position of chief engineer for the Toronto Electric Light and its subsidiary companies operating in the vicinity of Toronto and Niagara Falls. Mr. Clark's office is now located at No. 12 Adelaide street, East, Toronto, Ont.

Mr. R. E. Schaulin, manager of the lamp sales department of the Pittsburgh district office, has been transferred to the Chicago district office. He has been succeeded by Mr. H. J. Solon, of the Pittsburgh office.

The fifteenth annual session of the American Mining Congress is to be held at Spokane, Wash., November 25-28.

PITTSBURGH SECTION A. I. E. E.

The opening meeting for the 1912-1913 season of Pittsburgh Section of the American Institute of Electrical Engineers was held in the auditorium, twenty-fifth floor of the Oliver Building, on September 10. The following officers were elected for the ensuing year: President, Mr. E. L. Farrar; secretary-treasurer, Mr. M. C. Turpin; directors, Messrs. F. L. Bishop, A. M. Dudley, W. O. Oschman, F. D. Newbury, F. E. Towne and J. W. Welsh.

A STEAM TURBINE DRIVEN CENTRIFUGAL PUMP

of 100 000 000 gallons per day capacity is to be installed in the Ross Pumping Station of the Pittsburgh Water Works by the DeLaval Steam Turbine Company, of Trenton, N. J. This pump will be the largest steam turbine-driven contrifugal pump ever built in this country, the rated capacity of 100 million gallons per day against a total head of 56 feet amounting to over 980 water horsepower. The pump is guaranteed to show a duty of 115 000 000 foot pounds per thousand pounds of dry steam, all steam used by the condensing equipment being charged to the main unit.

NEW BOOKS.

"Light, Photometry and Illumination"—William Edward Barrows. 334 pages, 196 illustrations. Published by McGraw-Hill Book Company, New York City. Price, $3.00.

This work is the outgrowth of a set of notes compiled for class-room work at the Armour Institute of Technology and of a previous work "Electrical Illuminating Engineering." It is intended as a text-book and for the use of practicing engineers. It deals principally with the fundamental properties of light, standards of illumination intensities, photometric methods, illumination calculations, and the principles of interior and street illumination.

"Introduction to the Study of Fuel." F. J. Brislee. 250 pages, 61 illustrations. Published by D. Van Nostrand Company, New York City. Price $3.00.

A technical book for those engaged in the pursuit of economy either in a boiler room or producer house. It deals principally with elemental chemical reactions; the analyses of fuels and products of combustion; the use of special measuring apparatus for high temperatures, gas qualities, etc.; calculation of the proper air supply and combustion temperatures. A classification of different fuels is made in which the distinguishing features of various grades are outlined briefly. Individual chapters are given over to discussions of producer and water gas and some of the few designs of apparatus employed; explosions and the explosion engine; testing and checking of boiler results, and the use of liquid fuel. The author does not pretend to take up the subject exhaustively but does go into its various ramifications sufficiently to give the engineer or student a good grounding in the underlying principles in fuel burning. E. D. D.

"Design of Electrical Machinery," Vol. II, Alternating-Current Transformers—William T. Ryan. 119 pages, illustrated. Published by John Wiley & Sons. Price, $1.50.

This book, like Vol. I, is intended for college students. It is now generally admitted that it is not feasible to develop a real designer in college, but much can be done in the way of teaching fundamental principles. In the latter part of the book a number of transformer designs, as worked out by senior students, are given.

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THE
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Accurate Voltage Regulation

Improvements in service rendered and closer relations with the public have been the trend of central station companies during recent years. The maintenance of close relations between the public and public service companies is at best a difficult matter. One of the most important means, whereby the consumer of energy for electric lighting judges the service rendered, is by the steadiness of the voltage supply. The public usually do not know the details of the elaborate power house equipment and distribution system necessary to give them continuity of service, for they do not come in direct contact with that part of the equipment. No other phase of the service more easily tends to create dissatisfaction among users than wide fluctuations in the candle-power of lighting units, speeds of motors, etc. On the other hand, a satisfactory voltage supply results in increased use of central station service.

The development of high efficiency lighting units and the impetus given towards the larger application of such illumination units along scientific engineering lines has also resulted in a corresponding increase in the requirements of steadiness of illumination. The best voltage regulation on any large system can only be obtained by the use of automatic regulating devices. Such devices should be rugged, should require a minimum of adjustment and should give practically instantaneous correction of relatively small voltage fluctuations. Naturally, complete apparatus possessing these qualifications to the most desirable degree was only obtainable by a process of development. The induction type feeder regulator, with auxiliaries for automatic operation, as described in Mr. Lehr's article, in this issue of the JOURNAL, fulfills such requirements.

During the past two years the number of installations of feeder regulating devices of this type has increased very rapidly, testifying to the desire of central station managers to furnish the best service that can be secured with available apparatus. Apart from the important question of voltage regulation in service and its effect upon the consumer, features such as improvement in regulation of

systems, economy of operation and distribution, increase in sale of light and power due to current consuming devices being operated at normal rated voltage, decrease in lamp renewals, etc., are also important factors, and show the desirability of installing automatic regulating equipment in transmission and central station distribution systems, from the standpoint of the operating company as well as the individual user of power.

A. D. FISHEL

Practical Utilization of Ozone

Thanks to the large amount of work done by various investigators, the commercial production of ozone has now become assured; and, as our knowledge of its effects is increased, it seems probable that the use of ozone as a sterilizer, as a bleaching agent, as a therapeutic agent and in general where a rapid oxidization is required, will become commercially feasible.

Ozone furnishes probably the most certain means of sterilizing water. Dilution, sedimentation and ground filtration are the natural processes of water purification. In artificial sedimentation basins, with slow operating velocities, sixty to eighty percent of the total solids may be separated, and a large percentage of the bacterial life (the objectionable part from the sanitary standpoint) will also be removed—in some cases as high as ninety to ninety-seven percent, according to Prof. R. L. Sackett of Purdue University, an authority on sanitary and hydraulic engineering. With concentrated populations there is increasing danger of contamination of water supplies and increasing difficulty in securing natural purification. Artificial means must therefore be resorted to, and the passing of ozonized air through the water furnishes a means of sterilization which leaves no trace of the purifying agent, as is the case where chemicals are employed. Municipal plants abroad have effected practically complete sterilization by this means on a commercially economical scale.

The value of ozone as a bleaching agent has long been recognized and a great deal of work has been done to commercialize this property, particularly where it is necessary that no trace of the bleaching agent remain, as for example, in the bleaching of flour.

It is also a germicide of great value and free from some of the objections which may be registered against other germicides, such as formaldehyde. Its use in the prevention and treatment of disease, also, will undoubtedly prove of great value to mankind.

C. E. SKINNER

Ozone and Health

Most elements, including oxygen, are more energetic when in a nascent state. Confined air is relatively stale; ozonizing revivifies its oxygen, and is accordingly a valuable adjunct to ventilating systems, where stale and vitiated air cannot be entirely displaced by fresh air. Sunlight is bactericidal. Tubercle bacilli are killed within a few minutes by exposure to direct sunlight, but an infinitude of bacterial life infests dark and damp nooks and corners where sunshine does not permeate. In such rooms tubercle bacilli do not die. Our houses admit too little sunshine; and too little air that has been acted upon by the sun enters them. The energy in sunlight that kills bacteria is probably the actinic rays. Another potent chemical energy possessed by out-door air, as a product of the sun's action, is ozone, generated in Nature's laboratory in various ways, as described in the article by Mr. W. H. Thompson in this issue.

If Nature goes to the trouble of producing ozone for the purpose of destroying the bacterial life that is inimical to man, and thus succeeds in making the earth habitable, surely man can well imitate Nature by the artificial production of ozone in the buildings from which he has excluded adequate air and sunlight. Too much ozone, however, may prove deleterious, as it would produce too rapid oxidation, just as too much concentration of oxygen in the air is injurious. The blood is capable of appropriating only a certain amount of oxygen, and too much free oxygen is as harmful as too little. Our endeavor should be to provide air indoors that is as suitable for breathing as that outdoors, but not to attempt to improve on Nature's composition of the air.

By decreasing the bacterial content of the air we breathe, ozone promises us a certain degree of immunity from infectious diseases. Its field is probably in preventing rather than in curing diseases, though it is useful for the latter. All expenditure of human effort—whether muscular, mental or emotional—produces some measure of fatigue. The athlete coming in from a Marathon, or other strenuous feat of endurance, is more quickly restored by inhalation of oxygen than by the administration of so-called stimulants. Similarly, in recovery rooms and rest rooms, there is need of high potential oxygen, so as to oxidize and eradicate from the blood more quickly and more permanently the fatigue products of exertion from whatever sources. The exhilaration of a brisk walk

in the early morning air can hardly be duplicated indoors, even though an ozone apparatus be in successful operation. It offers no substitute for exercise in the open air, but by improving the air we breathe, it promises to increase our comfort and safeguard our health. CHARLES A. LAUFFER, M. D.

Commercial Possibilities of Ozone

Ozone is probably creating more interest at the present time than any other of the many gases, on account of the promising possibilities which it offers in the several different branches of science. Two of these are probably more directly affected than all others—the electrical and the medical professions; the first in its manufacture and the second in its physiological use. The most efficient and economical means in use for obtaining this gas, as pointed out by Mr. Thompson in this issue of the JOURNL, is by electricity; therefore the problem of producing it economically, and thus enabling all to participate in its use will naturally be assumed by the electrical manufacturers.

In view, however, of the remote relations in daily business between these two fraternities, it is quite as impractical for the medical fraternity to keep in direct touch with the electrical manufacturer as it is for the manufacturer to keep in direct touch with them. Therefore, the problem of establishing a medium of exchange between the two will naturally fall upon the central station and electrical dealers, and it thus devolves upon them to keep the physicians in their respective vicinities informed as to latest developments in the methods of producing ozone.

There is, comparatively speaking, a very limited knowledge of artificially produced ozone today, yet, as pointed out by Mr. Thompson, where tried, it has, in the majority of cases, proven successful. This leads us to believe that its possibilities are even greater than commonly appreciated and that certain classes of the public, who heretofore have not been prepared to cope with certain diseases, will now be able to secure effective treatment. While the use of ozone in the treatment of diseases is of paramount importance, there are many other applications—for instance, we are told that the common house-fly will not remain in a room where ozone is being liberated. This in itself is quite sufficient to make the ozonizer a household necessity. C. E. ALLEN

NATURE, PRODUCTION, AND USES OF OZONE

W. H. THOMPSON

OZONE has probably been known to man since his very earliest existence as it is continually being formed by the various processes of nature, but it is only during comparatively recent times that it has been recognized as a distinct gas and given a name, and it is only within a very few years that it has been produced by artificial means with sufficient economy for commercial use.

The earliest record of artificial production of ozone is by a Dutch scientist named Van Marum, who in 1785 noted the peculiar smell after oxygen had been subjected to electrical discharges. This he termed the "smell of electricity," which was later noted by other investigators, but it is not recorded as having been recognized as a distinct gas until 1840, when a German scientist named Schoenbein, then a professor at the University of Basle, Switzerland, by exhaustive research proved it to be so and suggested its name, which is derived from the Greek and signifies smelling. He also discovered the action of ozone on potassium iodide and devised a rough method of measuring it, but during the next fifty years little additional knowledge was gained about the gas until in 1890 Berthelot, a French chemist, took up the study of it for the purpose of applying its well recognized properties to practical ends. Since that time interest in the subject has been rapidly increasing and great progress has been made towards developing efficient apparatus for the production of this gas. The development of the alternating-current transformer and generator has made possible a means of generating it economically and the more recent wide distribution and general utility of electric power in offices, homes and factories has opened up a wide field for electric ozone generators.

CHARACTERISTICS

Ozone is an allotropic form of oxygen which is many times more active than oxygen itself. It is considered as the strongest oxidizing agent known and on this account is of great value as a disinfectant and antiseptic, and has been used with great success for the sterilization of air, water and various substances, as well as for the relief and cure of diseases, particularly of the respiratory organs. It has generally been considered as differing chemically from oxygen; oxygen being designated as O_2, meaning that the atoms are arranged in pairs of two for each molecule, while ozone is

designated as O_3. In this state the atoms are very unstable and are ready to unite with any oxidizable substance with great activity. It is this characteristic that gives ozone its great sterilizing and germicidal powers.

Pure ozone is a colorless gas, heavier than air, with a penetrating odor somewhat resembling the odor of chlorine. It is unstable in the presence of oxidizable substances and instantly decomposes at a temperature of 260 degrees C., although at ordinary temperatures it decomposes slowly. It can be reduced to a dark blue liquid, by a pressure of 1 840 pounds per square inch at a temperature of 103 degrees C., when it is highly magnetic but less active, chemically, than the gas.

Owing to its great activity, ozone will remain but a short time in the presence of an oxidizable substance, or in any air or water containing germs or floating particles of animal matter. Its presence can be detected by smell even when diluted to one part in ten million. An odor of ozone is an indication that the air is fairly sterile, because if there were impurities or bacteria in the air the ozone would immediately attack them and thereby be neutralized. In addition to its remarkable oxidizing and sterilizing powers it is also a very strong bleaching agent and has been used with considerable success commercially for bleaching flour.

METHODS OF PRODUCTION

Ozone is produced in the atmosphere by a variety of natural processes. It is usually present in the open country near the sea or large bodies of water, waterfalls and forests, but it is not commonly found in cities, except after a thunder storm or after a sudden change in temperature or some other unusual condition. It is often very noticeable after heavy lightning discharges, and the peculiar freshness of the air is largely due to the presence of ozone. It is also formed by the action of the ultra-violent rays of sunlight on air. It is a well-known fact that the best time for bleaching clothes, for example, is in the early morning before the dew has disappeared. The reason for this, and the fact that on a bright morning, with dew on the grass, the air seems so refershing, is probably that the many tiny drops of dew act as prisms, refracting the rays of sunlight, so that the ultra-violet rays acting on the air generate a considerable quantity of ozone. The concentration produced by natural processes is never very high, that is to say, the proportion of ozone to air is small and when it is produced momentarily by sudden lightning discharges it is soon diffused after the discharges

cease. Various estimates made on the proportionate amount present in the air, indicate that it rarely exceeds one part to one million of air. As it quickly attacks oxidizable substances it cannot remain long in the atmosphere of cities where there is always a large amount of such matter suspended in the air.

The most efficient of the present known methods of producing ozone artificially and the one used most commonly is that in which air or oxygen is passed over the corona or brush discharge from suitable terminals connected to a high voltage alternating-current circuit. Other methods which might be mentioned are: Oxidation of phosphorus in moist air; oxidation of certain essential oils, such as turpentine; subjecting air or oxygen to sudden change in temperature by passing it over a heated non-metallic substance, such as a Nernst glower; by radiation from radio-active salts; by electrolysis of water, sulphuric acid and certain other liquids; by mixing fluorine and water; by the action of sulphuric acid on permanganate of potash; by the action of ultra-violet rays, as from a mercury arc in a quartz tube, upon air or oxygen.

FORMS OF GENERATORS

The forms of ozone generators, or "ozonizers," as they are usually called, are many and varied. Up to the present time more than one hundred and twenty patents have been taken out on such apparatus. The earliest of these is dated 1809, but fully 75 percent of them have been taken out since 1897. The earlier forms were designed to operate from static machines or induction coils, while the later ones are nearly all designed to operate from high voltage alternating-current transformers. While the majority of the early ozonizers were inefficient and impractical, they formed the stepping stones to the present practical apparatus. The progress which has been made in their efficiency of production is shown by the following:—

Date	Grams of ozone per kw-hr
1850	1
1897	7
1903	22
1908	34
1909	55
1910	70
1911	116

The various forms of ozonizers include those of the spark-gap type, the flat plate type, and the tube type. The spark-gap type usually has two or more terminals consisting of a number of points between which sparks are made to pass from a source of high

voltage, and over which air passes and is ozonized. The difficulties with this type are that destructive arcs often start between the terminals and also that there is considerable oxide of nitrogen formed together with the ozone. The arcing may be avoided by a condenser connected in series with the spark-gap, but this greatly reduces the amount produced.

The flat plate type consists of flat plates of dielectric material, usually of glass, on one side of which is a conducting coating. The plates are arranged in pairs, with the conducting coatings on opposite sides and a small air-gap between the uncoated surfaces through which the air passes and is ozonized when a high potential is applied to the coatings, causing a discharge to take place across the gap between the plates. A modification of this type consists in using, instead of two plates of dielectric, one of perforated metal with a number of points adjacent to the uncoated surface of the glass plate. A discharge takes place between the metal points and the glass plate, ozonizing the air.

In more recent designs a glass tube is used for the dielectric, which makes a much more substantial arrangement, both from a mechanical standpoint and from the standpoint of insulation. The arrangement is usually such that the ozone is generated inside the tube, the air being passed through either by natural flow produced by the slight rise in temperature within the tube, or by a forced draft produced by a fan. In ventilating rooms of ordinary size such as offices and dwellings it is not necessary to have a forced draft of air as the natural currents of air are sufficient to circulate all the ozone required. In theatres, large work rooms and places where a large number of people congregate, a fan or blower will be found useful for distributing the ozonized air.

Some ozonizers have been rendered unsuccessful by the efforts of designers to produce the maximum amount of ozone from a given size of apparatus. The results of these designs have been the production of nitrogen oxides in addition to ozone. These are not only disagreeable, but harmful. It is therefore very important that the parts of ozonizers be so proportioned as to produce a negligible amount of nitrogen oxides.

An ozonizer can be designed so that practically pure ozone is produced, the amount of nitrogen oxides being the merest trace. It can safely be said that the ozone produced from apparatus so designed is for all practical purposes absolutely pure. A portable type of ozone generator of such design is illustrated in Figs. 1, 2

and 3. The ozone is generated inside glass tubes lined with metal mesh, the outside of the tubes being plated by a special process with a thin coating of metal closely adherent to the glass. This form of generator has proven to be of very high efficiency, while the surface and voltage are so proportioned as to produce the purest ozone possible. This design is extremely rugged and substantial; the electrically active parts are highly insulated, and the apparatus is almost noiseless in operation, so that it can be left running, even in a sleeping room, without the slightest disturbance. The design is, moreover, such that in ordinary use, i. e., with the cover in place, all live parts are inaccessible, so that the apparatus can be handled with safety even while in operation. There are no rotating parts, the three essential elements being, four generating



FIGS. 1 AND 2—PORTABLE ELECTRIC OZONIZER.
Exterior and interior views.

tubes, a step-up transformer and a regulating switch located inside the case at the top and connected to the generating tubes so that by turning a knob, on the top of the case, to one of the four positions indicated on the dial the number of tubes in operation may be regulated. Thus, with the switch pointer at 1 there is but one generating tube in operation; with the pointer at 2 twice as much ozone is generated; while, at 3 or 4, there is a proportionate increase.

In using this apparatus one tube in operation should usually be sufficient for a room of ordinary height, 10 to 12 ft. square, while four tubes in operation should produce sufficient ozone for a room ranging in size from 20 to 40 ft. square. Very large rooms with many people may require more than one ozonizer. The opera-

tion of the apparatus is most efficient when it is so located in a room that there is free circulation of air about it; the ozonized air is then distributed throughout the room most effectively. The best location is probably near the floor, but the generator should be kept in a dry place. It should be connected to a circuit having nominally the same voltage and frequency as those indicated on the name plate of the apparatus. Connection is made from the low-tension side of the transformer to the electric light circuit by means of an attachment plug and connection cord which forms part of the equipment. The ozonizer may be left on the circuit indefinitely, as the amount of heat developed during constant operation is negligible and the amount of power consumed is very small, viz., approximately 18 watts with all four generating tubes in operation.



FIG. 3—TOP VIEW OF OZONIZER
Showing switch and dial, and outlet caps.

The transformer which is used in this apparatus is of a special design, which gives compactness and ruggedness combined with efficiency. The coils are wound on thoroughly insulated spools, assembled on an iron core, and placed in a welded sheet metal box which is filled with an insulating compound so as to completely impregnate and surround the coils. With this construction the transformer is heat proof and moisture proof. The connections between the transformer and the generating tubes are made through the regulating switch. With the switch in the / position, the four tubes operate in parallel directly across the high-tension side of the transformer; the voltage being that required for the most efficient production of ozone. When in operation, one high-tension terminal of the transformer is connected to the outer metal coating on the glass cylinder forming the generating tube, while the other high-tension terminal is connected to the wire mesh which lines the interior of the tube. The production of ozone is due to the uneven distribution of potential on the inner surface of the generating cylinder caused by the mesh, which results in a large number of minute brush discharges. These brush discharges are

accompanied by a sufficient amount of heat to slightly warm the air, and this, with the tendency of the transformer to give off heat causes the air to rise in a positive direction up through the tubes. There are no obstructions in the tubes and their diameter is such as to allow free passage of air.

MEASUREMENT OF OZONE

It is now possible to measure the quantity of ozone in the air quite accurately. The method which has been in use up to the present time was roughly devised by Prof. Schoenbein in 1840, but has since been improved and made accurate by the correct evaluation of constants. This method consists in passing the gas to be measured through a solution of potassium iodide which contains approximately one percent of free sulphuric acid. Iodine is set free by the ozone according to the following reaction:—

$$2\,KI + H_2O + O_3 = I_2 + O_2 + 2\,KOH$$

The K O H which might otherwise absorb the free iodine is taken up in the following reaction.

$$H_2SO_4 + 2KOH = K_2SO_4 + 2H_2O$$

The amount of free iodine can now be determined by mixing with starch solution and titrating* with sodium thiosulphate. This reaction is as follows:

$$2I + 2Na_2S_2O_3 = 2NaI + Na_2S_4O_6$$

It can be determined from the molecular weights that in the above reaction one gram of sodium thiosulphate is required for 0.0800 gram of ozone and from this the amount of ozone absorbed in the solution can be calculated.

A method recently proposed by Chas. Baskerville and W. J. Crozier consists in using potassium cadmium iodide, $CdKI_3$ instead of potassium iodide; otherwise the process is the same as the above. The reaction is as follows:—

$$2\,CdKI_3 + H_2O + O_3 = 2I + 2KOH + Cd(OH)_2$$

This method is reported as being more accurate than the previous method, as the end reaction point is sharply defined and the results are the same for both acid and neutral solutions.

PHYSIOLOGICAL ACTION OF OZONE

The human blood contains approximately five million red corpuscles per cubic millimeter; any excess or deficiency indicates some disturbance in the health equilibrium. The red corpuscles contain a proteid known as hemoglobin (the coloring matter of the blood). This hemoglobin is rich in iron, which possesses an affinity

*When the starch solution is added to the solution containing free iodine, the combination at once becomes blue in color. The titration consists of adding measured quantities of a solution of known strength of sodium thiosulphate until the blue color disappears. This is called the "end reaction point" and occurs when just enough sodium thiosulphate has been added to unite with all the free iodine present.

for oxygen. When the blood is well charged with oxygen it is rich in oxy-hemoglobin; when it is deficiently aerated, it contains an excess of carbon-dioxide-hemoglobin. In the internal physiological processes of the body the blood has to give up its oxygen in order to maintain life, and must receive its new supply of oxygen through the lungs. It is thus apparent that an abundance of air, sufficiently rich in oxygen, must be available for breathing into the lungs, if a healthy condition is to be maintained. Physical exertion in the open air may increase the circulation and the amount of inspired air as much as seven fold; exercise is the ideal method of aerating the blood.

Buildings which are too large for ordinary methods of ventilation may require such methods as are applicable, for example, to mines. Overcrowding of rooms, and noxious fumes not adequately eliminated by methods of forced ventilation, likewise necessitate some means of improving the oxygen content of the confined air. Under these conditions an approved type of ozone generator is applicable. Air which has been vitiated to some degree may be restored, and the fresh air supply may advantageously be ozonized. With the air thus purified, deodorized and oxygenated, the health and efficiency of those living in such confined quarters is greatly enhanced.

Ozonizers of the type here illustrated are designed primarily for use in rooms of ordinary size, such as offices, dwellings, etc., as indicated above. It should be plainly understood, however, that the operation of this apparatus is not intended to take the place of ordinary ventilation. The ozonizer must be supplied with air containing oxygen in order that it may generate ozone. The introduction of fresh air into a room simply dilutes the impure air, but does not destroy the impurities. The effect of ozone is to destroy the impurities by the process of oxidation. The ozonizer does not add any oxygen to the air; it simply renders the oxygen which is present more active. For general purposes, the amount of ozone required varies, of course, with the size of room and the number of people present, and can best be determined by trial. One part of ozone in one million of air is sufficient, and if there is more than a slightly perceptible odor this fact may be taken as an indication that the proper proportion has been exceeded; if the odor of ozone becomes at all noticeable or becomes disagreeable or irritating, the rate of generation should be reduced.

A large amount of valuable data has been collected on the beneficial effects of ozone in the treatment of certain diseases. The

following extract from "High Frequency Manual" by Eberhart is interesting:—

"Ozone increases the oxygenation of the blood and tissues, increasing oxyhemoglobin and also increasing the number of red blood corpuscles. It is claimed that a decrease in white blood corpuscles is produced, if they are above normal. In a strongly concentrated form, ozone is destructive in its effect on mucous membrane, and even to life itself. Germs are destroyed by it and it has been shown capable of so thoroughly disinfecting sewage that the filtered water was pronounced suitable for drinking purposes. It is distinctly deodorant—even a small ozonizer running in a room will quickly destroy the most objectionable odors.

"In a Chicago bank an ozone machine was placed in a room where six employees were working. Their weight and chest expansion was taken at the time the machine was installed, and again in sixty days. The result is shown in Table I.

"*Indications*—In one sense of the word, since oxygen is so essential, it might easily be claimed that ozone is indicated in any bodily ailment, and I am of the opinion that its inhalation would be beneficial to the extent that pure air would be desirable, but there are some diseases in which it is of particular benefit. Among these are anemia; all diseases of the respiratory or-

TABLE I.

No.	Weight		Chest Expansion	
	Nov. 6.	Jan. 6.	Nov. 6.	Jan. 6.
1	147.5	148.25	31 —34	37 —39
2	118	121.5	31.5—34.75	31.5—36
3	130	131.25	30 —34.75	30.5—36.5
4	123	126.75	30.5—34.25	30.5—36.75
5	134	138.5	30.5—35	31 —37.5
6	118	117.50	29 —31.75	29 —32.5

gans, including tuberculosis; infectious diseases; and all conditions where there is imperfect oxidation and impaired nutrition. An ozone spray has been demonstrated to be healing in all forms of ulcers, etc.

"*Methods of Administration*—As ordinarily employed, ozone is administered in the form of inhalations in the physician's office, or by ozonizing the air of the room which the patient occupies. In employing the ozone directly from the generator, it has been found necessary to filter it through essential oils in order to remove the nitrous and nitric oxides.* Oil of pine needles, two parts, and oil of eucalyptus one part, is a favorite form. In many instances it seems to me to be much more sensible to administer constantly ozonized air than to depend upon occasional inhalations. This is especially true in consumption."

Effect on Nutrition.—The following is taken from reports by Doctors L'Abbe and Oudin before the Paris congress for the study of tuberculosis:—

"We investigated the influence of ozonized air on nutrition in general, and especially in anemia (impaired blood) or persons physically reduced. When the percentage of oxyhemoglobin is below normal (say 9 or 10 percent), as is usually the case with tuberculosis patients, inhalations of ozonized air for a quarter of an hour increase it by one percent. The increase, temporary at first, becomes permanent after a number of treatments, and

*This is based on the assumption that a form of apparatus is used in which the ozone is generated in high concentration, and therefore contains nitric and nitrous oxides. Such types have been used more or less in times past by physicians for administering ozone to patients by direct breathing through tubes. This statement, therefore, does not necessarily apply in the case of generators producing pure ozone.

one can affirm that at the end of two or three weeks' treatment, the patient has reached a normal figure.

"This is necessarily accompanied, in the case of anemic patients by more energetic oxidation, more rapid combustion, which calls for more rapid renewal of nutritive materials (increased metabolism), and from this there speedily arises an increase in appetite, which in some patients takes the form of a demand for food such as has been hitherto unknown to them, with return of strength, disappearance of complications, in short, restoration to health.

"Out of a number of patients weighed before and after treatment, including those in all stages of tuberculosis,

One	gained	1.1	lbs.	Six	gained	3.3	lbs.
Three	"	4.4	"	Two	"	2.5	"
One	"	6	"	One	"	6.6	"
Two	"	7.7	"	Three	"	8.8	"
One	"	9.9	"	One	"	11.	"
Two	"	15.2	"	One	"	19.9	"
One	"	23.1	"	Two remained stationary.			

"With the return of flesh there was a corresponding increase in oxyhemoglobin, as follows:

Two	gained	1	percent	Ten	gained	3	percent
Five	"	1½	"	One	"	3½	"
Four	"	2	"	Six	"	4	"
Five	"	2½	"	One	"	5	"

Four were not examined.

In view of the reputation and standing of the physicians making this report, more than ordinary consideration should be accorded the statements.

Dosage—It is claimed that large amounts of ozone are capable of producing death, and that rabbits have succumbed in ten minutes in an atmosphere containing eight milligrams of ozone to the litre. The proper proportion for therapeutic inhalation is one, two or three milligrams to the litre. Inhalations given in a physician's office last from ten to twenty minutes and may be repeated frequently. The indications that the patient has had sufficient dose is usually a slight sensation of lightheadedness.

Tuberculosis of the Lungs—Ozonizing the air of the patient's room is the best method of employing ozone in this disease. H. de la Coux, chemical expert to the Council of the Perfecture of the Seine, Paris, says:—

"In the application of ozone for tuberculosis, it is an undeniable clinical fact that the number of bacilli in the sputum diminishes after the second or third treatment, even before the general condition of the patient is improved."

Dr. George Stoker, of the London Throat Hospital and the Stoker Oxygen Hospital, reports nine cases of tuberculosis treated within a year at the latter hospital, of which eight were discharged with the disease definitely arrested.

"In advanced cases with cavities and much expectoration, I think there is no means of so much use as inhalation of ozone. It empties the lungs of detritus (products of disintegration) and pus, revivifying the blood, disinfecting the parts of the lungs reached, and after the first irritation of its use has passed off, there is nothing that gives the lungs the sense of rest and quiet as does this agent. I have seen the quantity of sputum lessened to

a most remarkable degree, and fever disappear, and all symptoms improve by the use of ozone inhalations."

Sletoff has treated 147 cases of tuberculosis with ozone with favorable results.

Anemia and Chlorosis—In a paper read before the American Pediatric Society, Boston, Dr. A. Caille reports the favorable influence of ozone in a number of cases of chlorosis and anemia, as well as other diseases, and in his conclusion says:—

"In chlorosis and anemia, ozone inhalations are exceedingly valuable from a therapeutic standpoint, and give better and prompter results than any other form of medication."

Chronic Middle-Ear Deafness and Tinnitus—Dr. Stoker has published a series of twelve cases of chronic dry catarrh of the middle ear with deafness and in nearly all with tinnitus (roaring of the ears), which were treated with an ozone spray. Improvement, sometimes remarkable, occurred in every case. The technique consisted in passing the ozone "in a gentle current through an eustachian catheter into the middle ear for about four minutes at a time, the operation being repeated several times a week, daily if possible."

Whooping Cough (Partussis)—The efficacy of ozone in treating whooping cough has been attested by many authorities. In practically all of these cases the ozone was administered in ten to twenty-minute inhalations. Ozonizing the air in the patient's room should prove a better method. L'Abbe says:—

"My personal experience rests on over 100 cases. In all, I have obtained amelioration, prompt and rapid at first, and later a complete cure in a time ordinarily covered by a very light attack. Ozone is the remedy par excellence for whooping cough."

Asthma, Bronchitis and Hay Fever are benefited or cured by ozone. Inhalations combined with ozonization of the air of the room is the method; the latter being more efficacious. Hay fever victims have found that the use of a room ozonizer constantly for two or three months prior to the expected attack has prevented the latter from coming on. During the attack inhalations have given great relief.

COMMERCIAL USES OF OZONE

The many possibilities which have been predicted for the use of ozone in commercial processes are amazing. These uses are fast increasing as more widespread knowledge and greater experience are gained regarding its properties. In many of these applications, special types of ozone generators would have to be used. The production of ozone in more concentrated form would probably be required, but this might not be open to the objection which

arises in the case of the physiological uses of ozone, viz., the product of harmful by-product nitrogen compounds when so generated. The sterilization of air and water are probably among the most important uses of ozone, but in addition may be mentioned the following, many of which are in use commercially:—

Preserving of food products in storage rooms; the growth of mold and fungi is prevented.
Bleaching of flour, sugar, starch, woolen and cotton goods, and feathers.
Treatment of oils by ozone destroys bad odor and rancidity.
Bad odors and tobacco smoke are quickly destroyed by ozone.
Operating rooms, bandages, instruments, etc., may be sterilized and kept sterile.
The oxidation of paints, oils and varnishes is hastened.
Sewage can be purified.
Laundry work can be made to smell fresh and clean, and be entirely free from the usual laundry odors.
Kitchens, cellars, storage rooms, etc., can be rendered odorless.
Water for swimming pools may be sterilized.

The purification of water and air by means of ozone has come into more extended use in Europe within the past few years than in the United States. Recently the "Tuppenny Tube" of the Central London Railway has been equipped with ozone ventilating plants at each station, where air is drawn in from the outside, filtered and ozonized and delivered to the tube. The average plant delivers from 5 500 to 7 500 cubic feet of air per minute; there are, however, two of these plants which deliver 12 000 and 20 000 cubic feet per minute, respectively. Altogether over 80 000 000 cubic feet of ozonized air is pumped into the tunnels daily. Tests in this installation have proven very satisfactory and have shown the air to be greatly improved. Previous to installing this ozone ventilating system it was found impossible to get a satisfactory condition of air by the exhaust system which had been in use for the past eleven years.

Ozone has been used with great success by many cities in Europe for the purification of the city water supply. The following European cities have ozone water purification plants:—

St. Petersburg, Paderborn, Wiesbaden, Paris, Hermanstadt, Florence, Nice, Chartres, Villefranche, Rovigo and Chemnitz. The City of St. Petersburg is supplied from two plants aggregating 12 500 000 gals. daily. Two ozone plants have been installed near Paris with a daily output of 12 000 000 gallons.

The fact that the above mentioned large plants, for the purification of air and water, have recently been installed, after several years' experience and the accumulation of valuable data from a large number of plants of various capacities, indicates that ozone is destined to soon become an important factor in many commercial processes as well as in the purification of air and water.

FEEDER VOLTAGE REGULATION

E. E. TEHR

POWER for city lighting can be produced most economically in large central stations with large generators operating in parallel on common bus-bars. Usually the area supplied with power is large and for convenience is divided up into small districts which are fed by individual feeders. The variation in voltage at the end of a long feeder may be considerable, due to change in voltage drop in the line with decrease or increase in load. The most satisfactory method of maintaining a uniform voltage over the entire system under all conditions of load is by the use of an individual automatically controlled regulator on each feeder. These are usually installed in the generating station, but frequently in very large systems they are installed in sub-stations. In the latter case power is transmitted at a high voltage from the generating station to a number of sub-stations where it is stepped down to a comparatively low voltage. It is then distributed to the surrounding districts by means of feeders, the respective voltages of which are controlled by automatic regulators. The regulators in this case not only take care of the drop in the feeders, but also compensate for any variation in the sub-station voltage due to a drop in transmission from the main power house.

Formerly it was sometimes attempted to obtain uniform voltage over the entire distributing system by the use of multiple busses obtained either by taps brought out from the generator windings by means of auto-transformers, or by separate generators. As the load increased, the large feeders were transferred to the busses having a higher voltage. This method had the objection that it complicated the switchboard and station wiring. Very close voltage adjustment could not be made, as usually only two or at the most three voltages were available. This method also made it necessary to interrupt the power for an instant while throwing from one bus-bar to another. It was also impossible to take care of sudden or frequent variations. Due to the increasing popularity of the electric motor, power companies found their power load constantly increasing and the power-factor correspondingly decreasing. There was also a tendency to increase the average length of feeder circuits to take care of the outlying urban districts. Both these tendencies had a detrimental effect upon the inherent voltage regulation of feeder circuits and had to be taken into account by the power companies.

It is now recognized that the most satisfactory and efficient method is to operate at a single voltage with all generators in parallel. This requires the use of individual feeder regulators in order to maintain a high standard of service throughout the system. Step type regulators are quite satisfactory for hand operation, as they are usually not operated very frequently. When adapted for automatic service they become more complicated, due to the increased number of steps required. When automatically controlled they operate much more frequently than when controlled by hand, and the question of repairs and contact renewals becomes of increasing importance.

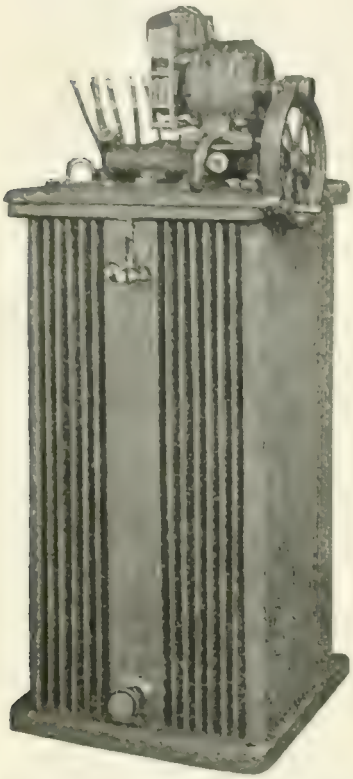


FIG. 1—SINGLE-PHASE, OIL-INSULATED, SELF-COOLED INDUCTION REGULATOR

Practically all regulators recently installed are of the induction type. Their superiority is due to their greater simplicity and to the absence of moving contacts upon which burning can take place. A modern single-phase induction regulator is shown in Fig. 1. A view of the regulator removed from its tank is shown in Fig. 2.



FIG. 2—SINGLE-PHASE REGULATOR REMOVED FROM TANK

The tank is of the sheet iron "cast in" type, which has proven so successful for transformers; the walls are of corrugated sheet iron and are welded by means of the oxy-acetylene flame. The

top and bottom are cast around the ends of the tank walls insuring a tank free from leaks. The magnetic circuit is built up in a short skeleton frame to which the top and bottom brackets are bolted. The top cover is also bolted to the top bracket.

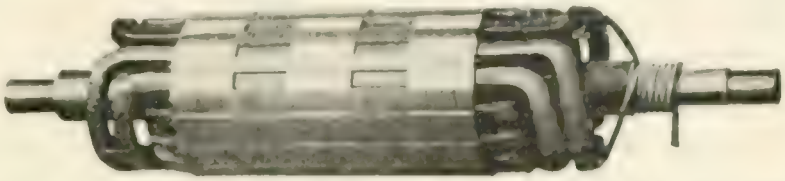


FIG. 3—ROTOR OF SINGLE-PHASE, OIL-INSULATED, SELF-COOLED INDUCTION REGULATOR

Certain features of design may be seen by reference to Fig. 3, which shows the rotor removed from the stator. The partially closed slots into which the short-circuit coils are wound have a marked influence on the performance of the regulator. They reduce the magnetizing current very materially, and also reduce the

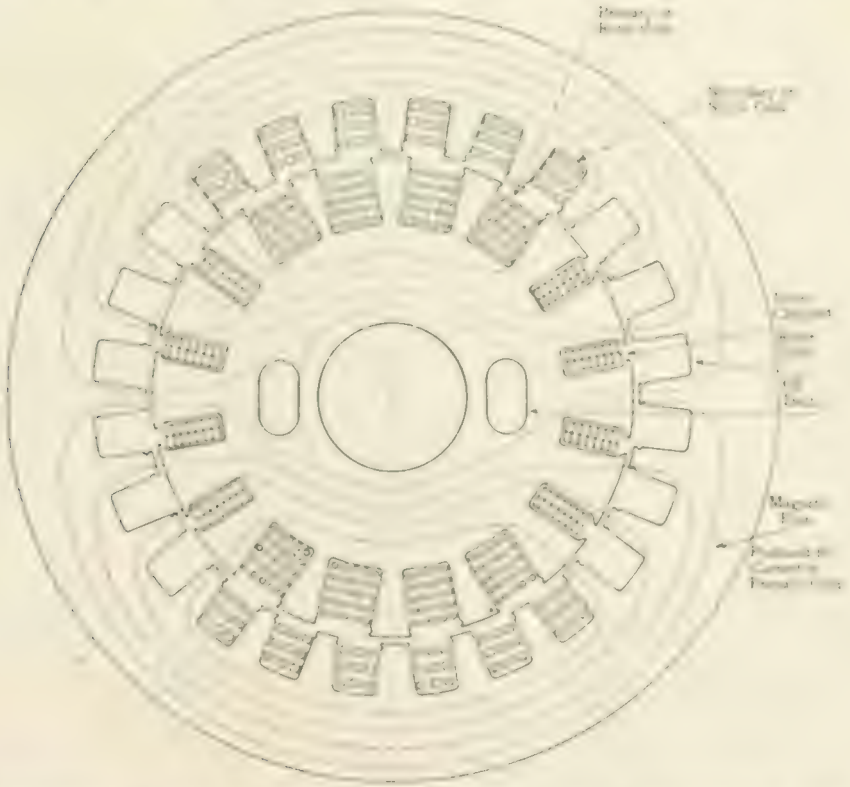


FIG. 4—SECTIONAL VIEW OF SINGLE-PHASE REGULATOR WITH ROTOR IN POSITION OF MAXIMUM BOOST

Practically all the flux produced by the primary or rotor windings passes through the series or stator coils.

torque required to turn the rotor, as they practically eliminate magnetic locking action between the rotor and stator teeth. No banding wire is used on the rotor as all coils are held in place by means of fibre wedges driven into grooves near the top of the slots.

A horizontal section of the magnetic circuit of the regulator is shown in Fig. 4 with the rotor in the position of maximum boost. Practically all the magnetic flux produced by the primary or rotor winding passes through the stator winding and induces a voltage in the stator winding. The rotor is shown in its neutral position in Fig. 5; in this position the flux produced by the primary windings has no effect upon the secondary windings. If in this position, the line current is flowing in the secondary winding, this winding will also act as a magnetizing winding and will tend

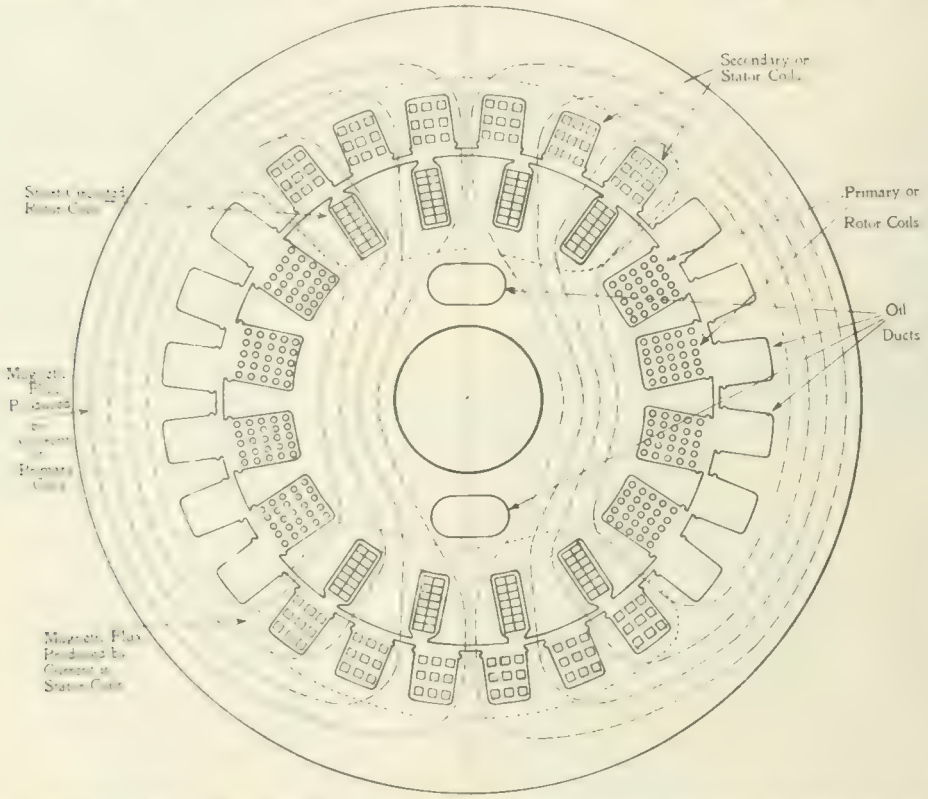


FIG. 5—SECTIONAL VIEW OF SINGLE-PHASE REGULATOR WITH ROTOR IN MID OR NEUTRAL POSITION

None of the flux produced by the primary or rotor windings passes through the series or stator coils. The dotted lines represent the flux produced by line current in the series windings, which is practically all neutralized by the short-circuited windings in the partially closed slots.

to send a magnetic flux through the secondary windings and through the short-circuited coils. As the resistance and reactance of the short-circuited coils are very low, only a small flux is required to induce enough current in the short-circuited coils to practically neutralize the magnetizing action of the secondary current. It is in this way that the short-circuited coils prevent an excessive choking action of the line current in the secondary when the regulator is in the mid position. The short-circuited winding is used only for the purpose of preventing this choking action; but its use is

essential, as otherwise the self-induction would be so great as to make the regulator inoperative.

The rotor is turned by means of a worm segment and worm mounted respectively on the shaft and top cover of the regulator. When the regulator is automatically controlled, it is operated by means of a motor and the motor must be provided with an efficient brake. One of the essential requirements of an automatic regulator is that it be stopped immediately after it has brought the voltage to its normal value. If the motor drifts to any great extent and the regulator over-travels, hunting is liable to result. A regulator motor must sometimes stand the most severe service to which any motor is put. It is common for a regulator motor to start and stop five or six times a minute, and there are installations, on lighting circuits fed from generators which also supply a railway load, where the motor is required to start and stop as often as thirty times a minute.

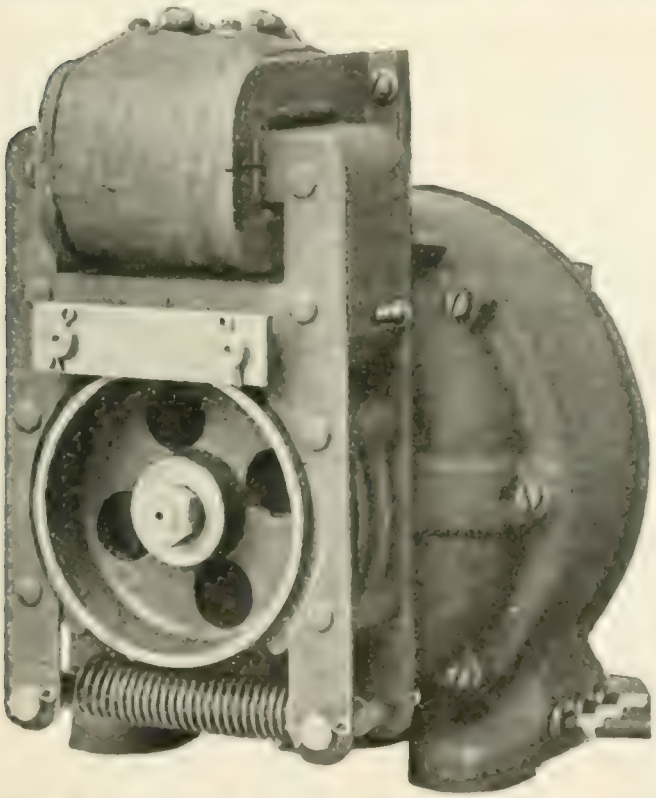


FIG. 6—OPERATING MOTOR AND ELECTRICALLY CONTROLLED, SPRING OPERATED BRAKE FOR INDUCTION REGULATORS

For the early automatic regulators, the motors and brakes were built along the lines usually followed for small power apparatus, but it was found that for severe service the life of this apparatus was comparatively short. A motor and brake specially designed for use with regulators is illustrated in Fig. 6. All loosely supported magnet armatures, toggle joints, connecting links, etc., are eliminated. The brake proper consists essentially of five parts, shown in Fig. 7. Half the magnetic circuit and one brake shoe are combined into one piece and rigidly riveted together, and supported by a hardened pin which is pressed into and forms an integral part of the motor bracket. The operating coil is wound on a brass spool which is firmly attached to a projecting lug on the motor bracket. The brake wheel is attached to a tapered end

of the motor shaft and is held in place with a key and nut with positive lock washer, following the standard practice used in mounting pinions on street railway motors. The only bolts or screws used in the construction of the brake are those for supporting the magnet coil, and they are provided with positive lock washers.

This design permits the use of an extremely small travel for the magnet armature and brake shoes, and a very rapid action of the brake is thus secured. The small travel also reduces the wear of the moving parts to a minimum. Special features have also been embodied in the motor design which makes it peculiarly adapted for rapid and frequent starting and stopping. The shaft is larger in diameter than is usual for a motor of this size. Oil ring bearings are provided. The pinion is attached to the shaft in the same manner as the brake wheel.



FIG. 7—OPERATING MOTOR AND BRAKE
With brake completely dismantled to show small number of parts.

In order to bring out any defects which might develop, one of these motors with its brake was subjected to a very severe life test. The motor was operated by means of a standard auxiliary relay and the relay was controlled by means of a contact-making device so that 72 starts and stops were made per minute. This gave sufficient time for the motor to come up to speed and also time for it to be stopped by the action of the brake before current was again thrown on in the reverse direction. This motor was in continuous operation, day and night, for over nine months and made approximately 25 000 000 operations. No repairs were made and no attention was given the motor except to oil it occasionally. Although this test represents the equivalent of approximately ten years average service, the brake shoe linings showed practicaliy no signs of wear, and no defects of any sort were discovered.

A limit switch is mounted on motor-operated regulators to prevent over-travel of the regulator. The limit switch is so constructed that when the regulator reaches the end of its travel the power of the motor is cut off and further movement in the same direction is prevented, but no interruption in power is made if the motor is operated in the opposite direction.

For the automatic control of a feeder regulator there are required, a primary relay or contact-making voltmeter with its series resistance and the necessary voltage transformer, an auxiliary relay or motor switch, and a line drop compensator with a suitable current transformer. A primary relay, as shown in Fig. 8, consists essentially of a solenoid in which is suspended a plunger which controls two sets of contacts. Attached to the moving element is a small auxiliary armature which is acted upon by two auxiliary coils known as compounding coils. When contact is made in the relay, current flows to one of the auxiliary relay coils and also to one of the compounding coils. This compounding coil attracts its armature and increases the pressure on the contacts just at the instant contact is made. When the contacts open the circuit to the auxiliary relay, the current in the compounding coil is also interrupted and the small additional pressure due to the compounding coil is eliminated just at the instant the contacts separate. These compounding coils cause the contacts to open and close positively and this eliminates chattering. They prevent the making of a succession of poor contacts, which, if not prevented, would cause abnormal arcing and burning and sometimes "freezing" of the primary relay contacts. The eliminaton of chattering is extremely important since any useless operation of the primary relay is transmitted to the auxiliary relay, motor and brake, which causes unnecessary wear and tear on all the apparatus. Compounding coils also so affect the operation of the relay that there is a greater tendency for the voltage to be held at the exact normal value than at the maximum or minimum value for which the relay is set. In case of a gradually increasing voltage, a relay without compounding coils tends to hold the voltage at the maximum value for which it is set, while with a gradually decreasing voltage there is a



FIG. 8.—PRIMARY RELAY

This is in effect a contact-making voltmeter.

tendency for the voltage to be held at the minimum value. This is shown more clearly by means of Figs. 10, 11 and 12.

Assume a circuit upon which the voltage gradually raises from a normal value of 110 up to 112 volts, remains at that point for a short time and then gradually decrease to 108 volts, as shown in the curve Fig. 10. Figs. 11 and 12 show the voltage curves obtained with regulators on this circuit controlled respectively by relays without and with compounding coils, if the relays in both cases are adjusted to operate on a variation of one volt plus or minus from a normal pressure of 110 volts. Referring to Fig. 11, as soon as the voltage reaches 111 the relay makes contact and the regulator reduces the voltage, but as soon as voltage is reduced very slightly

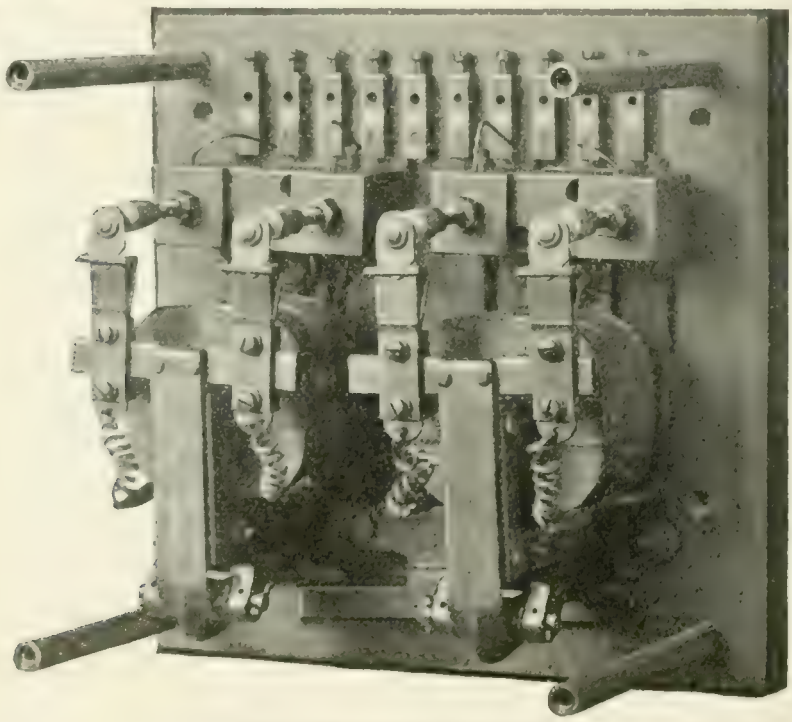
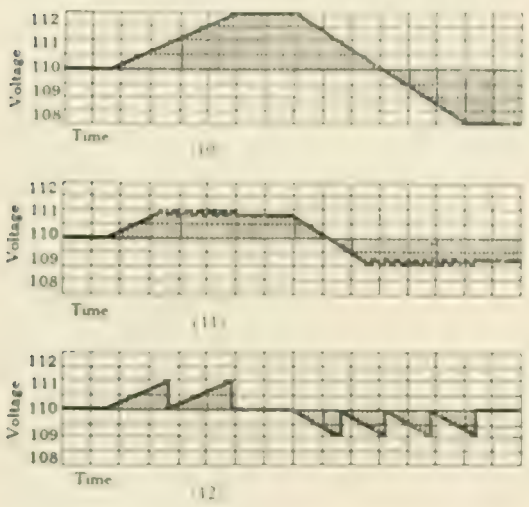


FIG. 9—AUXILIARY RELAY
With cover removed.

below 111 the relay contacts open and stop the regulator. As the voltage is gradually increasing it again reaches 111 and the regulator again operates and reduces the voltage just slightly below 111. Referring to Fig. 12, when the voltage reaches 111, causing the relay contacts to close and the regulator to start, the contacts do not open immediately after a slight voltage reduction is made, because the compounding coil is energized and the strength of this coil is such that the voltage must be reduced approximately 0.5 volt before the contacts can open. This permits the motor on the regulator to come up to speed so that it will then drift slightly and return the voltage practically to the exact normal value. A

study of the two curves will show that the average variation from normal is much less when compounding coils are used than when they are omitted. It can also be seen that better regulation is obtained with fewer operations of the relays and regulator.

As the primary relay is essentially a voltmeter, it is not suitable for the operation of contacts for the control of the motor, and accordingly an auxiliary relay, such as shown in Fig. 9, becomes necessary. This relay consists essentially of two clapper type electro magnetic switches similar to those used for the control of large power motors, except that they are particularly designed for regulator service. Each switch consists of a magnet riveted to a supporting frame which also supports the bearing pin for the arature. The two frames are mounted on a slate base and are connected by a casting which also supports the interlocking bar. The armature punchings are riveted to a phosphor bronze casting which is supported by the bearing pin in the supporting frame. Two insulated contacts are mounted on a cross-arm attached to each armature and these make contact with stationary contacts mounted on insulated supports fastened to the slate base.



FIGS. 10, 11 AND 12—THEORETICAL VOLTAGE CURVES, SUCH AS WOULD BE OBTAINED WITH A CURVE TRACING VOLTMETER, ILLUSTRATING EFFECT OF COMPOUNDING COILS ON PRIMARY RELAY OPERATION.

Fig. 10—Assumed line voltage. Fig. 11—Voltage obtained with regulator operated from relay without compounding coils. Fig. 12—Voltage obtained with regulator operated from relay equipped with compounding coils.

The most regulators are used in connection with outgoing feeders fed from a common set of bus-bars, where it is necessary to adjust each feeder independently in order to take care of the line drop in each feeder under various load conditions. A compensator is therefore necessary in order that the relay may be so affected that it will increase the voltage of the feeder in proportion to the increase in load and thus maintain a constant voltage at the center of distribution. The compensator is connected to a current transformer and in series with the primary relay and is so de-

signed that a voltage proportional to the current is induced in the relay circuit consisting of the primary relay coil and the relay resistance. Connections are so made that this small induced voltage opposes that of the voltage transformer and, as the load increases, the regulator automatically raises the voltage more and more. Fig. 13 shows a complete diagram of connections for an automatically controlled motor-driven induction regulator.

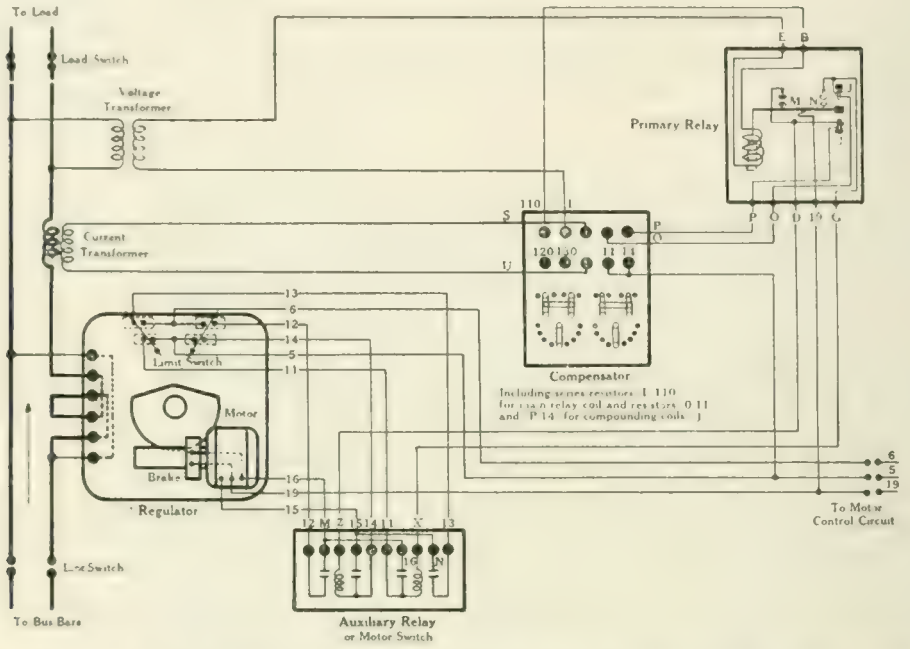


FIG. 13—DIAGRAM OF CONNECTIONS FOR SINGLE-PHASE INDUCTION REGULATOR AND ITS AUXILIARY APPARATUS FOR AUTOMATIC CONTROL

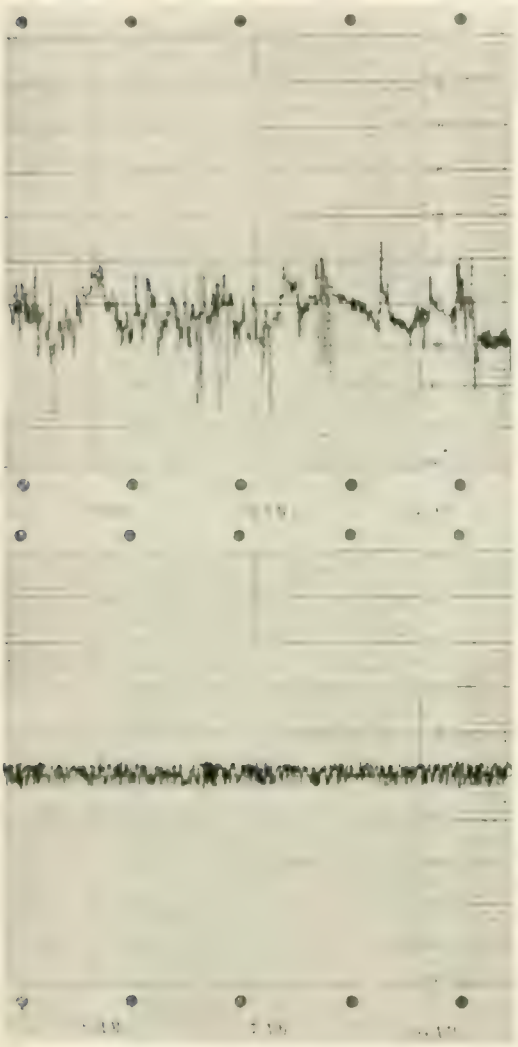
With high voltage, the left hand contacts close at *M* and current flows from *19* through lower compounding coil *J*, through *P-14* to *5*, and also flows from *19* to *D*, and through the secondary relay coil *Z-14* to *5*. The secondary relay then closes *M-12* and *15-14*, and starts the motor, which operates the regulator to reduce the voltage.

With low voltage, the right hand contacts close at *N*, and current flows through the upper compounding coil *J*, and also through the secondary relay coil *X-11*. The secondary relay then closes *16-11* and *N-13*, and starts the motor in a reverse direction, which operates the regulator to raise the voltage to normal.

When the rotor of the regulator turns in a clockwise direction to the extreme position, the limit switch opens the connections between *5* and *11* and between *6* and *13*. When in the extreme clockwise position, the connections between *5* and *14* and between *6* and *12* are opened.

It is sometimes desirable to use a "no-voltage" relay whose function is to bring the regulator to the maximum buck position in case the voltage goes off the line. Without this relay, if the power goes off the line and if the current to the operating motor circuit is not also interrupted, the primary relay will act in the same way as for any reduction in voltage and will bring the regulator to the maximum boost position. When the full voltage again comes

on the line an excessive voltage may be produced on the regulated side of the circuit, but it will be corrected almost immediately by means of the primary relay. A "no-voltage" relay consists of a shunt electromagnet which is energized by the voltage transformer and which controls two sets of contacts. Although not shown in Fig. 13, its operation can be understood by referring to this diagram. The circuit *19* to the primary relay is made to pass through one set of contacts which is normally closed. If the electromagnet is deënergized this set of contacts opens and the other set closes and connects *19* directly to *D*. This brings the rotor to the maximum buck position, and if the power is again connected to the line no excessive voltage is obtained.



FIGS. 14 AND 15—CURVE TRACING VOLTMETER CHARTS

Fig. 14—Taken on single-phase lighting circuit fed from an interurban railway power system.

Fig. 15—Taken on the same circuit after passing through a single-phase regulator controlled by automatic relays and operated by a motor which moves the regulator throughout its complete range in approximately eighteen seconds. Although the regulator operated at a relatively slow speed, very satisfactory regulation was obtained, notwithstanding the fluctuating source of power.

COMMERCIAL IMPORTANCE OF CLOSE VOLTAGE REGULATION

The maintenance of constant potentials on distributing systems not only indirectly produces more revenue for the central station by the increased use of power resulting from the satisfactory service, but it directly increases the sale of energy and results in a very considerable saving in the cost of lamp renewals. Without automatic regulation it is very probable that the voltage will be

lowest on the consumer's circuit just at the time that he needs the largest number of lights, because at this time the voltage drop in the feeder is at a maximum. When it is remembered that for a given number of lights the power consumed varies at the square of the voltage, it can readily be seen that low voltage may easily be the cause of a considerable decrease in power consumption.

When individual feeders are not used there is always a tendency to adjust the voltage for average conditions so that a con-

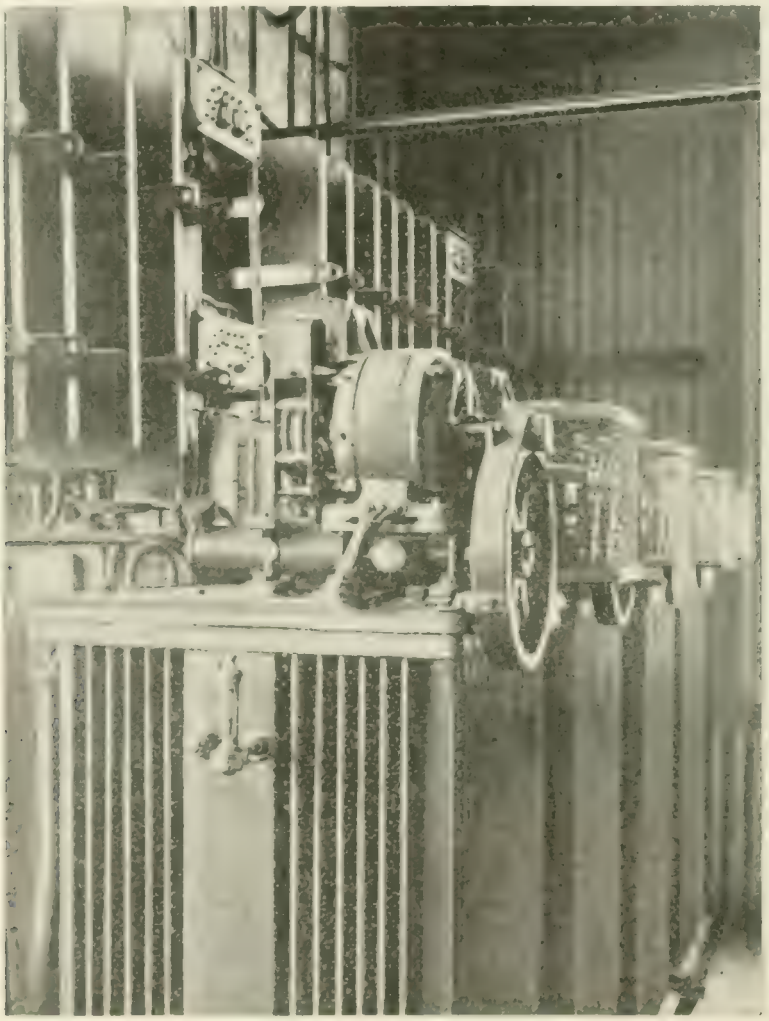


FIG. 16—INSTALLATION OF AUTOMATIC SINGLE-PHASE INDUCTION REGULATORS
Public Service Electric Company of New Jersey.

siderable number of lights must be operated at an excessive voltage. The life of a light depends very decidedly upon the voltage at which it operates and decreases rapidly as the voltage is increased. A 30 percent decrease in the life of a lamp with a four percent increase in voltage is not an excessive figure, and it is at once apparent that a considerable saving in lamp renewals will result if a constant voltage is maintained.

CARE AND OPERATION OF TRANSFORMERS*

W. M. McCONAHEY

LARGE high-voltage power transformers require a reasonable amount of care in order that they may give satisfactory service. It will not do to install such transformers and put them into service and then expect them to operate year in and year out with practically no attention. The larger the size, and particularly the higher the voltage, the more important it becomes that they receive careful and intelligent inspection.

Within a few years the sizes of units and the transmission voltages have increased greatly, so that a few suggestions, particularly to operating men, on the care and operation of transformers seem of timely importance. It is the intention to deal mainly with oil-insulated transformers, although many of the points brought out will apply equally to the air-blast type.

INSULATION AND HEATING

There are two essentials to be considered in the design of transformers, namely, insulation and heating. There are other points to be taken into account, such as efficiency, regulation, adaptability to various classes of service, etc., but the only practical effect they have is to modify the proportions of the design. The insulation must be of good quality, of sufficient amount and properly distributed, and the provisions for ventilating the windings and dissipating the heat must be such as will keep the temperature within reasonable limits. Assuming that these conditions have been met by the manufacturer, the operating man must do his share towards maintaining the insulation in good condition, and preventing excessive heating by prolonged heavy overloads. With intelligent and systematic care, there is practically no end to the life of a well-designed modern transformer.

The principal insulating material used in transformer manufacture, known as "press-board" or "fuller-board," is of a fibrous nature. It is made up in large sheets varying in thickness from a few mils to about one-eighth inch, although in large transformers it is generally not used in thickness of less than one-sixteenth inch. It is cut and formed into the proper shapes and assembled with the coils so as to give the necessary dielectric strength in the various

*A portion of this article was presented at the Seattle convention of the National Electric Light Association, June, 1912

parts. From this it is seen that the fuller-board is depended upon to furnish the insulation between the various parts of the windings and between the windings and ground, and that it must be maintained in good insulating condition if the transformer is to have long life and continue to operate without giving trouble.

Since fuller-board is of a fibrous nature, it has a tendency to absorb moisture. No satisfactory method has yet been devised for treating the fuller-board so as to make it entirely impervious to moisture, or has any satisfactory substitute been found that will meet the requirements. It is necessary, therefore, in order to protect the insulation, to use such means in operation as will prevent as much as possible the entrance of moisture into the transformer case and to remove any that may enter, before it has had time to cause serious trouble.

CARE OF THE OIL

Formerly it was customary, in shipping transformers, to pack them separately from their tanks. When shipped in this manner it was practically impossible to prevent the insulation from absorbing moisture, even when special methods of packing were resorted to. Such schemes as packing in tin-lined cases or placing calcium-chloride inside of packing cases never proved very satisfactory, so that before putting transformers into service it was nearly always necessary to dry them out. This required time and care and a certain degree of expert knowledge which made it very desirable that some method of shipping be devised which would make it unnecessary to dry them out before installing. This is now accomplished by bracing the transformer securely in its tank, filling the tank with oil and shipping in this manner. The only limit imposed upon this method of shipment is the inability of the railroads to handle very large sizes because of insufficient clearances. This has been overcome to a considerable extent by the use of a special form of "drop frame" car with the floor much lower than that of an ordinary flat car.

When a transformer is shipped in its own tank with the oil it should arrive at its destination with the insulation and oil practically dry and free from moisture. In order to make sure of this, however, it is best to draw a few samples of oil from the bottom of the tank and test them. The best way to make the test is to use some standard form of testing cup and a variable ratio testing transformer by means of which the voltage can be raised gradually. The cup is filled with a sample of the oil, the gap is adjusted to a

fixed length with a micrometer screw and the voltage is raised until a spark jumps across the gap through the oil. It is customary to set the gap at about 150 mils, and with such a setting good oil will show a break-down insulation strength of not less than 30 000 volts, *i. e.*, 200 volts per mil of gap for an average of ten tests. A variable ratio testing transformer may not always be available, but no company using transformers should be without an oil-testing cup. If no means of varying the voltage is at hand, so that it is necessary to use a fixed voltage for making the test, the gap should be set to give 200 volts for every mil of separation and break-down should not occur at this setting. In making tests in this way, however, it is not advisable to use a testing voltage below 6 600 volts. If the tests on samples of oil as taken from the transformer, shipped in its tank with the oil, are satisfactory, it is a practically sure indication that the transformer is dry and ready to put into service.

Cleanliness is essential to good service, and it is important for the life of the transformer, particularly if it be of high voltage, that the tank be closed up tightly so as entirely to exclude dust and dirt. This is done by packing tightly around all outlet bushings and placing gaskets under the cover, and also under the hand-hole and man-hole covers. In very large transformers the gaskets are often made so that the tank can be made practically air-tight, but in medium and small sizes the gaskets are generally made of felt or hemp treated with a moisture-proof compound. It is surprising how much dirt can gradually work its way through a very small crack, so that it should not be taken for granted that small openings are harmless. To allow a transformer to operate with a loose-fitting cover or with openings not closed is inexcusable negligence which will be paid for by a shortened transformer life.

After the transformer has been installed and put in successful operation, a periodical inspection should be made about once every six months. Such an inspection should include a test of a sample of the oil drawn from the *bottom* of the tank and an examination of the interior. If a test of the oil shows the presence of too much moisture, or an inspection shows a deposit of dirt or slime in the transformer, the oil should be drawn off, filtered and de-hydrated, and the transformer and interior of the tank should be thoroughly cleaned with dry, clean waste. The ventilating ducts can generally be cleaned by squirting dry oil through them. If the transformer is water-cooled the cooling coils should be examined to find out

whether any deposit has been formed on them by the oil. Some oils will form a coating on the cooling coils which acts as a heat insulator and results in the transformer running hot. This deposit can be removed only by scraping and rubbing the coils until they are clean. Good transformer oils, as they are supplied today, will form little or no deposit. They are also reasonably clear, so that by the use of an incandescent lamp a very good inspection of the upper part of the windings can generally be made without the necessity and inconvenience of lowering the oil until the coils are exposed.

If the oil in a transformer is found to be in a dirty condition or to be forming a deposit, it should be filtered, and if it is found to contain moisture, steps should be taken at once to remove this moisture. The filtering process can be performed easily by passing the oil through two or three thicknesses of bolting cloth. One passage through the cloth will nearly always be found sufficient to remove all the dirt or deposit.

The removal of moisture is not such an easy task. Various make-shift schemes have been tried, but all seem far from satisfactory. Some of these schemes are: Placing bags of dry lime in the oil, passing hot air through the oil, or heating the oil so as to vaporize the moisture and drive it off.

In order to remove the moisture completely and leave the oil in first-class condition, it should be passed through some standard form of de-hydrator designed particularly for the purpose. Probably the best form of this class of apparatus is known as the filter-press type. In this type the oil is pumped through several thicknesses of a specially prepared paper. The paper has the peculiar property of allowing the oil to pass through freely, while at the same time retaining every bit of moisture until it becomes saturated. When the paper approaches saturation, it should be removed and replaced by fresh dry paper. This is the most successful method that has yet been devised for removing moisture from oil; it is very simple and removes the moisture entirely, leaving the oil in a clean, dry condition. An exceedingly simple and satisfactory way of keeping the oil clean and dry is to connect a small de-hydrator outfit to a transformer tank in such a way that the oil can be pumped from the bottom of the tank through the de-hydrator and back again into the tank at the top. The connection at the bottom can be made through the oil-valve. The necessary connections can be made and the de-hydrator put into service without in any

way interfering with the operation of the transformer. A small, cheap dehydrator having a capacity of about two gallons per minute can be had which is particularly suitable for this work. It can be kept in operation continuously until the oil is clean and dry. This method of caring for the oil should appeal to operating men because of its simplicity and convenience.

CARE OF THE INSULATION

The insulation of transformers is liable to absorb moisture either as a result of failure to keep them in the oil or as a result of the presence of enough moisture in the oil to greatly reduce its insulating value. In such cases it may be necessary to dry the insulation in order to prevent break-down. Proper measurements of the insulation resistance from the high-tension winding to the low-tension winding and to the core, and from the low-tension winding to the core, will serve as approximate means of determining its condition.

Measurement of Insulation Resistance—Insulation resistance measured with the transformer cold is nearly always much greater than when measured with it hot. Therefore, in order to determine the condition of the insulation, the transformer should first be heated up by internal heat, or, preferably, by both internal and external heat, to a temperature of from 75 degrees to 80 degrees C. After it has reached this temperature it should be maintained there for 24 hours. The insulation resistance may then be taken and, in general, it may be said that if it measures below about one megohm per 100 volts of transformer rated voltage, for example, about 1 000 megohms for a winding for 100 000 volts or above, drying out will be necessary. These resistance values are based on the assumption that the measurements are made when the transformer is heated up. Unfortunately this measurement is not ordinarily a convenient one to make because of lack of the necessary facilities. The insulation resistance can be determined very easily with a "megger," but, as such an instrument is not generally available, the next best method is to use a direct-current voltage of 500 or 600 volts and a high resistance voltmeter. A special voltmeter having a resistance of about one megohm should be used, if it can be had, as the resistance of the ordinary direct-current voltmeter is too low to give very satisfactory results. With this method the voltage across the line is measured first, and then the voltmeter and resistance to be measured are connected in series across the line

and another reading taken. The insulation resistance is then calculated from the formula,—

$$R = \frac{r(V-v)}{v}$$

in which R = resistance of insulation.
r = resistance of voltmeter.
V = direct-current voltage across the line.
v = voltage reading with insulation in series with voltmeter.

Connections for making these measurements are shown in the diagram, Fig. 1. By using a voltmeter such as may be obtained for such measurements, having a resistance of one megohm, the calculation is simplified, since r becomes equal to unity, and the above formula becomes,

$$R = \frac{V-v}{v} = \frac{V}{v} - 1$$

Great care must be taken, in connection with all such insulation measurements, to insulate all wiring for the test, since resist-

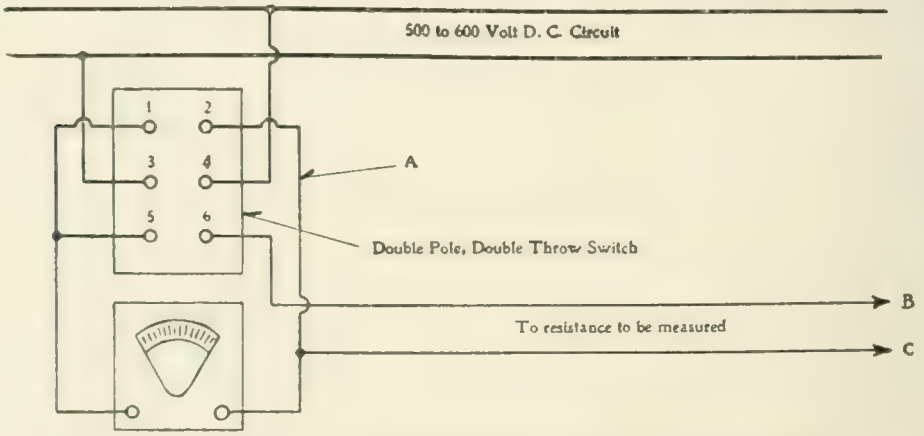


FIG. 1—CONNECTIONS FOR MEASURING INSULATION RESISTANCE

ances of several hundred megohms have to be measured. The best way is to use wires stiff enough to support themselves so that they can be run directly between the points to be connected without any intervening supports. When transformers are dried by the vacuum process, described below, the wires can be run into the case through the high-tension bushings which, when clean and dry, should have an insulation resistance high enough to prevent the readings from being appreciably affected. The voltmeter should be placed on a table that rests on dry, well-insulated supports. A double-pole, double-throw oil switch is preferable to an ordinary switch mounted on a marble base, because of the greater insulation resistance between the contacts in the former.

For measuring the insulation resistance of the high-tension winding, wire C, Fig. 1, should be connected to it and wire B to the low-tension winding or to the core, according to whether the

measurement is being made from the high-tension to the low-tension winding, or from the high-tension winding to the core. When the insulation resistance from the low-tension winding to the core is being measured, wire *C* should be connected to the low-tension winding and wire *B* to the core.

After the connections have all been made, check readings should be taken to insure that there is no appreciable leakage of current between the switch jaws. To do this, close the switch on 5 and 6, Fig. 1, and note accurately the voltmeter reading. Then disconnect wire *A* from 2 and leave the end hanging free in the air and, with the switch closed on 5 and 6 as before, take another reading very accurately. If this reading is appreciably less than the first one, the insulation resistance across the switch jaws is too low. In such cases, all readings of insulation resistance must be taken with wire *A* disconnected. In reading the line voltage, connect wire *A* up again and close the switch on 1 and 2.

Methods of Drying—There are four principal methods of drying out the insulation of transformers, viz., 1—by internal heat; 2—by external heat; 3—by internal and external heat, and 4—by the vacuum process.

Internal Heat—With this method alternating-current is required. The transformer should be placed in its case without the oil and the cover left off to allow free circulation of air. The low-tension winding should be short-circuited and sufficient voltage impressed across the high-tension winding to circulate enough current through the coils to maintain the temperature at from 75 degrees to 80 degrees C. About one-fifth of normal full-rated current is generally sufficient to do this. The impressed voltage necessary to circulate this current varies within wide limits among different transformers, but will generally be approximately 0.5 to 1.5 percent of normal high-tension voltage at normal frequency. The end terminals of the winding must be used, not taps, so that current will circulate through the total winding. The amount of current may be controlled by a rheostat in series with the high-tension winding.

As this method is slow and, at best, superficial, it should be used only with small transformers, and then only when local conditions prohibit the use of one of the other methods.

External Heat—For drying with external heat, the transformer is removed from its case and a wooden box is built around it, with holes in the top and near the bottom to allow circulation of air. The clearance between the sides of the transformer and the box

should be small so that most of the heated air will pass up through the ventilating ducts among the coils and not around the sides. The heat should be applied at the bottom of the box.

The best way to obtain the heat is from grid resistors, using either alternating or direct current. The temperature limits are the same as for the first method, using internal heat. The transformer must be carefully protected against direct radiation from the heaters. Care must also be taken to see that there is not inflammable material near the heaters, and to this end it is advisable to line the lower part of the wooden box with asbestos. The heater should preferably be placed in a separate box, the heated air being conducted to the bottom of the transformer through a suitable pipe. Where this plan is followed, the heat may be generated by direct combination of gas, coal or wood, provided great precaution be observed not to allow the products of combustion to enter the box surrounding the transformer. However, heating by combustion is not to be advocated except where there is no source of electric power. This method, while effective, requires much longer than the following one, in which combined internal and external heat is employed.

Internal and External Heat—In combining the two foregoing methods, the current should, of course, be considerably less than when no external heat is employed. This method is used occasionally where direct current only is available, a certain amount of current being passed through the high-tension winding only, as the cross sectional area of the low-tension conductor is generally too large for it to be heated with an economical amount of direct current. The use of direct current for drying out is not recommended except where alternating current cannot be obtained.

In addition to being quicker than either the first or second method used alone, the combining of the two results in the insulation being heated much more uniformly, which is obviously a great advantage.

Vacuum Process—The vacuum process can be used only with the larger sizes of water-cooled transformers which have the cover bolted down over an air-tight lead gasket to a cast-iron ring riveted to the top of the case. In brief, it consists in placing the transformer in its case without the oil, closing the case air tight, exhausting the air and, by means of alternating current circulated through the coils, bringing the transformer to a temperature somewhat above that which corresponds to the boiling point of water at

the reduced atmospheric pressure. Under a vacuum of 25 inches water boils at 55 degrees C.

With this process the transformer is dried thoroughly and uniformly, and at a low temperature, which reduces the risk of damage to fibrous insulation. It also allows the oil to be admitted to the case under vacuum, after drying, which effectually prevents the formation of air bubbles in the interstices of the windings and insulation. This is of great importance in large, high voltage transformers where it is necessary to have the oil entirely free from air. While the vacuum method is somewhat expensive and complicated, its use is justified for drying out large, high voltage transformers. Detailed instructions are issued by the manufacturers of large transformers for using this method.

No definite time can be specified as that required for drying out; it depends upon the condition of the transformer, its size and voltage, and the method of drying used. One to three weeks will generally be required. By plotting a curve of the insulation resistance measurements, for example, with *time* as abscissae and *resistance* as ordinates, the point where the insulation resistance begins to increase more rapidly may be determined by locating the knee of the curve. The total drying period should be about 115 percent of the time preceding the passing of this point.

Precautions—If the initial insulation resistance be measured at ordinary temperatures it may be high although the insulation is not dry, but as the transformer is heated up it will drop rapidly. As the drying proceeds at a constant temperature, the insulation resistance will generally increase gradually until towards the end of the drying period, when the increase will become more rapid. Sometimes the resistance will rise and fall through a short range one or more times before reaching a steady high point. This is caused by moisture in the interior parts of the insulation working its way out through the outer portions which were dried at first. As the temperature varies, the insulation resistance also varies, for which reason the temperature should be kept nearly constant and the resistance measurements should all be taken at as nearly the same temperature as possible. Measurements should be taken every few hours during the drying period, and the precaution should be observed of giving the apparatus constant attention.

As the drying temperature approaches the point where fibrous materials deteriorate, great care must be taken to see that there are no points where the temperature exceeds 85 degrees C. Several thermometers should be used and they should be placed well in

among the coils near the top and screened from air currents. Ventilating ducts offer particularly good places in which to place some of the thermometers. As the temperature rises rapidly at first, the thermometers must be read at intervals of about one-half hour. In order to keep the transformer at a constant temperature for insulation resistance measurements, one thermometer should be placed where it can be read without removing or changing its position. The other thermometers should be shifted about until the hottest points are found, and should remain at these points throughout the drying period. Whenever possible the temperature should be checked by the increase of resistance method.

When drying by the vacuum method, thermometers of course cannot be used, in which case the temperature of the transformer can only be determined by the increase of resistance method.

LOADING

Assuming that the necessary care is taken to keep the transformer clean and dry, it is equally important that it be not overloaded to such an extent that the insulation is damaged by excessive heating of the coils. Insulation will not stand prolonged heating at a temperature much above 100 degrees C. without permanent injury.

It is practically out of the question to determine the actual temperature of the copper, which is the hottest part, so that about the only guide the operating man has is the temperature of the oil. It is generally customary for manufacturers to guarantee that the temperature rise of the windings of power transformers when operating at normal load will not exceed 40 degrees C. above the temperature of the cooling medium (air or water). Going a little further and analyzing this 40 degree drop, it is found that it may be divided up approximately as follows: Copper to oil, 10 degrees, and from oil through tank to air or from oil through cooling coil to water, 30 degrees. These drops will vary considerably with different transformers, but the figures given represent a fair average. Assuming that the iron loss and copper loss are equal, if the load is increased 25 percent the copper loss will be increased 56 percent while the iron loss will remain constant, so that the total loss will be increased 28 percent. Roughly speaking, the different drops will be proportional to the amount of heat taken away, so that the drop from copper to oil for 25 percent overload will be increased 56 percent and that through the oil to the cooling medium 28 percent. Applying these increments, we find that the normal

load drops of 10 degrees from copper to oil and 30 degrees from oil to cooling medium are increased to approximately 15.5 degrees and 38.5 degrees respectively, or a total of approximately 54 degrees. That is, increasing the load 25 percent has increased the temperature rise of the windings from 40 degrees to 54 degrees. The standard temperature guarantees for power transformers when operating continuously at 25 percent overload is 55 degrees.

If the windings are well ventilated the maximum temperature will not exceed the average by more than a small amount, but if they are poorly ventilated there may be a wide difference between the maximum and average temperatures. From the above discussion it will be noted that as the load is increased the drop from copper to oil increases rapidly, so that for heavy overloads the temperature of the copper is much above that of the oil. For this reason, if it is necessary to put a heavy overload on a transformer for several hours, some judgment must be exercised in trying to determine from the temperature of the oil what the temperature of the windings is at the same time. If this temperature (not temperature rise) is allowed to get much beyond 100 degrees C., there is danger of the insulation being permanently injured.

There is quite a difference between a prolonged overload and one of short duration. Oil has the capacity of storing considerable heat, so that if a transformer is operated at a moderate temperature, quite a heavy overload can be thrown on suddenly and carried for such a time as is required to raise the oil to a temperature beyond which it is not safe to go because the temperature of the windings has approached the limit of safety. The thermal capacity of oil is such that one kw will raise the temperature of 11 gallons 1 degree C. per minute. Setting this in the form of an equation we have $t = \frac{11 \times kw \times T}{G}$ in which t = temperature in degrees C., kw = loss, T = time in minutes and G = gallons of oil. During the time that heat is being stored in the oil it is also being taken up by the circulating air if the transformer is self-cooling, or by the cooling water if water-cooled. While the transformer is being heated up under a steady load, the rate of storing heat gradually decreases and the rate of giving up heat to the cooling medium gradually increases until finally a steady condition is reached in which no heat is stored up but all is given to the cooling medium. During the heating-up process if the transformer is under heavy overload the temperature of the oil should be watched and should not be allowed to exceed a value which, ac-

cording to the approximate method given above for calculating temperature drop through the copper and oil, indicates a winding temperature exceeding 100 degrees C.

Large Self-Cooling Units—Self-cooling transformers can now be built in sizes up to about 2 000 or 3 000 kw, depending upon the voltage and frequency. These large sizes are particularly applicable where it is desirable to transform large amounts of power without artificial cooling and with a minimum amount of attendance.

Water-Cooled Units—The output for which water-cooled transformers can be built is limited only by the weight and the mechanical dimensions which make handling or transportation difficult. In very large sizes, it is sometimes necessary to ship the transformer in a more or less knocked-down condition and assemble the parts at destination. The reason that water-cooled transformers can be built in such large sizes is that cooling coils with sufficient radiating surface to take care of the large amounts of heat generated can be made without trouble.

The Water Rate—Water, because of its very high thermal capacity, is particularly suitable as a cooling medium. One kw will raise the temperature of 3.8 gallons of water one degree C. in one minute. Ordinarily the water rate is ¼ gallon per minute per kw-loss, which gives a temperature rise of 15 degrees C. from the inlet to the outlet of the cooling coil.

Increasing the water rate decreases its temperature rise in inverse ratio and the temperature of the windings is lowered approximately one-half the amount by which the temperature rise of the water is lowered. On the other hand, decreasing the water rate increases its temperature rise in inverse ratio and the temperature of the windings is raised approximately one-half the amount by which the temperature rise of the water is increased. As an example, if the water rate is increased from ¼ to ⅜ of a gallon per kw-loss, the temperature rise of the water will be decreased from 15 degrees C. to 10 degrees C. The average temperature of the water in the cooling coil is 2½ degrees lower for the ⅜-gallon rate than for the ¼-gallon rate, and therefore the temperature of the windings is also 2½ degrees lower. Thus it is seen that no very great gain is made by increasing the water rate. If, however, a heavy overload is placed on the transformer so that the temperature rise of the water is considerably increased, an increase in the water rate will help materially.

Some kinds of water will gradually form a deposit on the inside

of the cooling coil which will act more or less as a heat insulator, and may in extreme cases close up the opening in the coils entirely. The presence of this deposit can be detected by a decreased flow and an increased temperature rise of the water or by an increase in the temperature of the transformer. It can generally be removed by passing a solution of hydrochloric acid through the cooling coils.

A water-cooled transformer should not be operated except for a very short time without the circulation of water through the cooling coils. The transformer will heat up very rapidly and will soon reach a dangerous temperature. It cannot even be operated in this manner for any length of time without load, because the iron loss in itself is sufficient to raise the temperature above the danger point. In order to guarantee against overheating due to the stoppage of the flow of water, it is customary to equip water-cooled transformers with alarm contact thermometers, to which alarm bells can be wired for the purpose of giving warning if the temperature should rise too high.

Air-Blast Units—The use of air-blast transformers is comparatively limited, being confined chiefly to a few large centers. For cooling purposes there are required about 150 cubic feet of air per minute per kw of loss. The air pressure required varies from about ½ to 1 ounce, depending upon the size of the transformer. If the air-pressure is shut off from an air-blast transformer it can carry full load for only a few minutes before reaching a dangerous temperature. This will be understood easily when it is remembered that there is no oil to store heat, and since there is very little radiation, practically all the heat generated in the windings has to be stored in the copper. The thermal capacity of copper is very low, and therefore it heats up very rapidly.

Starting cold and throwing on full load, with the air-blast going, an air-blast transformer will reach steady temperature conditions in about two hours, while an oil-cooled transformer would require probably six to ten times as long. Because of the rapid heating up of the windings, an air-blast transformer cannot safely carry a heavy overload for more than a few minutes. The temperature rise of the windings under normal operation varies approximately in the same ratio as the copper loss. For example, if the temperature rise is 35 degrees C. under full load, it will be approximately 55 degrees C. at 25 percent overload.

This type of transformer should not be wound for voltages exceeding about 35 000 volts. Beyond this it is impractical to go because of the insulation difficulties encountered.

ELECTRIC POWER FOR TANNERIES

J. M. TOMB

EVERY progressive manufacturer is interested in the application of electric power in his particular industry. The tanning industry, however, has long regarded the generation of power in each plant to be more economical than purchased power, as so much low pressure steam is required in the manufacturing processes and it is thus necessary to have a boiler plant in any event. Until the adoption of the acid chrome method of tanning there was enough refuse tanbark to fire the boilers, with only the cost of handling this convenient fuel. The power requirements for leather making are characterized by a low commercial load factor. The true or running load factor, however, is quite high and therefore it is possible, by the proper arrangements of individual and group motor drive, to secure good operating efficiency and high power factor. The diversity factor in the operation offsets, to a large degree, the value that would exist in the use of exhaust steam for heating purposes, and this condition, together with the actual saving in energy required to do the work, tends to make central station service very successful.

The conditions of operation in a tannery are exceptionally severe on electric machinery, owing to the damp and acid laden atmospheric conditions. The motors must be especially impregnated to resist the destructive effects of the acid. Oil switches should be enclosed in moisture proof cases in order to avoid liability of breakdown. Without making a claim that electric power is specifically adapted to every condition of operation it is nevertheless a fact that in a number of large tanning factories electric drive is being used with economy and entirely satisfactory results.

As an example of an unusually successful installation of a motor-driven tannery the plant of the Leviseur & Conway Company at Salem, Mass., may be cited. This factory is at the present time turning out leather for the manufacture of shoe uppers which is known to the trade as "Caravan kid." This leather is made from sheep skins coming from countries where the climate is very warm and the pelt of the animal is covered with coarse hair, making the pores of the skin resemble those of goat skin. Some of the hides are received in a salted state while others are received in a sun-dried condition. The acid chrome process of tanning is employed, the

complete process requiring from three to four weeks, depending on the quality of the hides and their condition upon receipt. When it is completed the leather presents a soft, smooth appearance and is used for the top or vamp of shoes, according to the thickness of the skins. The daily capacity of the plant is from five to six hundred dozen skins, and the aim of the company is to produce uniform stock at a minimum cost for power, light and heat.

Three-phase, 60 cycle, 2200 volt power for operating the factory is received from the service wires of the Salem Electric Light Company. The voltage is reduced to 220 volts through a bank of transformers located on poles adjacent to the boiler house. There is also a separate set of transformers for lighting and op-



FIG. 1—TWO DOUBLE PADDLE WHEELS DRIVEN BY A 5 HORSE-POWER MOTOR; AND FIVE PIN WHEELS DRIVEN BY A 20 HORSE-POWER MOTOR

The double paddle wheels are set in large cylindrical vats, and serve to keep the hides and solution in constant motion. The pin wheels are eight feet in diameter, made of heavy two-inch planking, and are used for washing the hides in cold water.

erating electric irons. Wiring throughout the factory is rubber-covered, waterproof wire, run on open porcelain cleats, except the risers from floor to floor which are run in conduits. The use of individual motors or one motor to a small group of machines has made possible the arrangement of machines so that skins in a raw state could be received in one end of the building and routed through the various processes so as to utilize the floor space eco-

nomically, resulting in maximum production with a minimum amount of handling and labor. As in many other industries it is quite frequently necessary to operate one department overtime—through noon hour or evening. During such periods maximum production is possible with a minimum power cost.

Many of the machines are of such construction as to require an average power considerably lower than peak loads of short duration. It has often been the case that motors have been installed of sizes suitable for carrying the peak loads, with the result that the motors operated at low power-factors and usually with high



FIG. 2—SIX PADDLE WHEELS DRIVEN BY A 10 HORSE-POWER MOTOR. FOUR APRON PUTTING OUT MACHINE IN FOREGROUND

The apron on the putting out machine passes up and down with the hides between two spiral bladed rolls. One man puts a hide on the apron while a man on the other side of the machine throws in a clutch which lifts the apron up between the rolls, while the desired pressure is applied to the rolls by means of a foot lever. The rolls are then allowed to separate and the apron drops to its original position. This operation is repeated about twelve times per minute, one hide being "put out" at a time. Lifting the apron imposes the heaviest load on this motor, the load at other periods in the cycle equalling only the friction of the machine.

demand charges. In this installation the power requirements were carefully studied, resulting in the selection of motors suitable for continuous operation under average conditions and having sufficient overload capacity to meet peak load conditions. A comparatively

low total capacity of motors was thus secured, which is a big advantage when purchasing power on a maximum demand rate.

The ease with which machines may be located is illustrated in Fig. 7. A 10 hp motor (shown in the background) drives the main shaft on the second floor. At right angles to the main shaft and at a more convenient point, a 1½ hp motor drives a measuring machine. It is not necessary to elaborate on this arrangement to show the distinct advantage presented in motor drive over one main line shaft.

It is a fact that many tanneries require a large quantity of steam. This condition was realized at the time the central station offered service. To reduce steam consumption to a minimum the

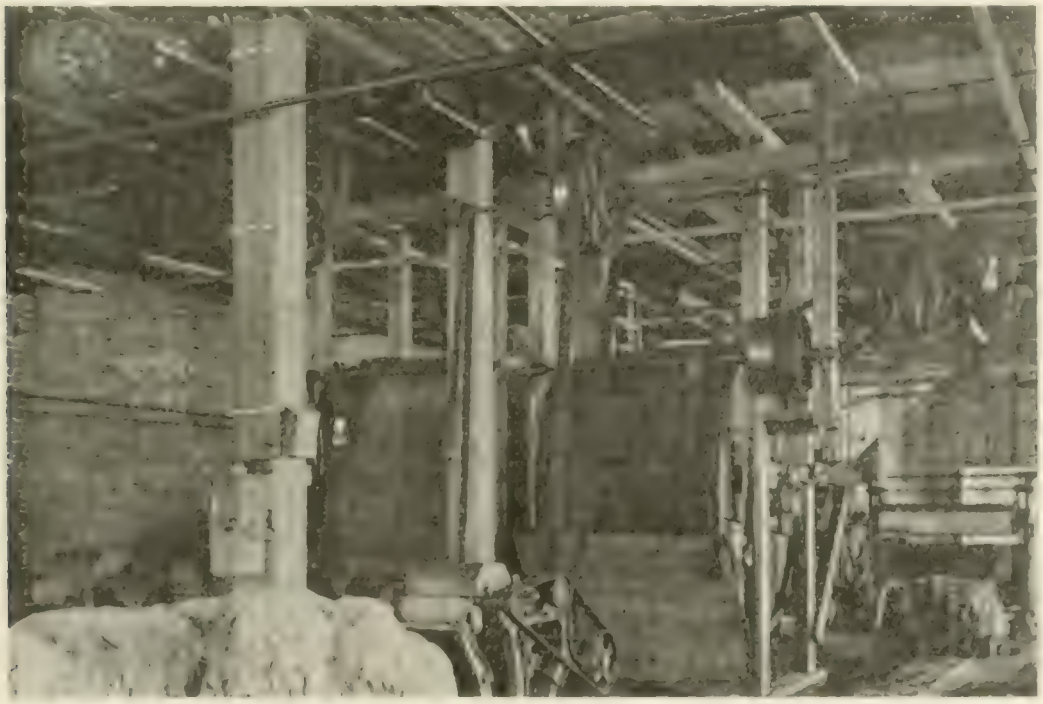


FIG. 3—TWO SHAVING MACHINES DRIVEN BY A 5 HORSE-POWER MOTOR. TWO COLOR WHEELS IN BACKGROUND DRIVEN BY A 10 HORSE-POWER MOTOR

The shaving machines remove any remaining flesh and smooth up the uneven surface on the flesh side after the tanning process. They consist of rapidly revolving bladed rolls against which the hide is pressed by rubber covered rolls actuated by foot-levers.

service of an expert steam engineer was secured, with the result that the steam system was arranged in a manner which decreased the coal consumption very materially.

The manufacturing operations in this factory may be divided into:—Beaming, wherein the hair and flesh are cleaned from the skins; tanning, which is done in pin drums and paddle tubs; and coloring and finishing.

Beaming—Regardless of whether the skins have been sun-dried or salted they are soaked in water to return them to their original state, which is greatly to be desired before starting the tanning process. If the hides carry a special amount and desirable quality of hair they are "limed," which loosens the hair from the skins so that it may be readily removed during the succeeding processes. Liming is seldom done, however, the hides being usually soaked in water. From the vats the hides pass to a double paddle wheel shown at the left of Fig. 1. These vats are semi-cylindrical in shape and the wheels are set at one side of the cylinder. The paddles serve to keep the hides constantly stirred up while they are soaked in a solution of hyposulphite of soda, which loosens the hair from the hides. From these paddles the hides go to the first set of pin wheels, shown at the right in Fig. 1 During the revolving of the wheels the hyposulphite is rinsed off by water with which the wheels were partly filled the hides being kept in constant agitation by wooden pins set on the inside of the drums The pin wheels revolve at approximately 18 r.p.m., being driven by a gear and pinion drive which is belted to the motor.



FIG. 4—CIRCULATING FANS, DRIVING WARM AIR FROM THE LOWER FLOORS INTO THE DRYING ROOM

The hides are then passed through a fleshing machine which takes off the flesh which is still clinging to the inside of the skins and also takes off the short hairs. The fleshing machine consists of a revolving roll on which are set a system of spiral blades which, moving at high speed, cut the flesh from the hides when they are pressed against the revolving cylinder by a hard rubber roll actuated through a lever by the operator's foot. The hides are fed through the two rolls by a third fluted roll about seven inches in diameter operating at 48 r.p.m. The operator feeds one roll at a time and fleshes about five hides per minute. The fleshing operation concludes the beaming or cleaning process.

Tanning—As a first step in the tanning process the hides are washed and then pickled in a brine solution in another set of pin wheels. From these wheels they are transferred into another set of paddle wheels, Fig. 2, where they are agitated in a solution of bichromate of soda (chrome) for several hours and then pass to the "putting-out" machines, shown in the foreground of Fig. 2, which lay out the grain in the leather, stretch it and draw out the surplus solution absorbed during the preceding processes. The "chromed" hides (now a pale yellow color) are thrown into paddle wheels containing a muriatic acid solution which oxidizes the chrome already in the leather giving a crystalline formation which, it is stated, gives

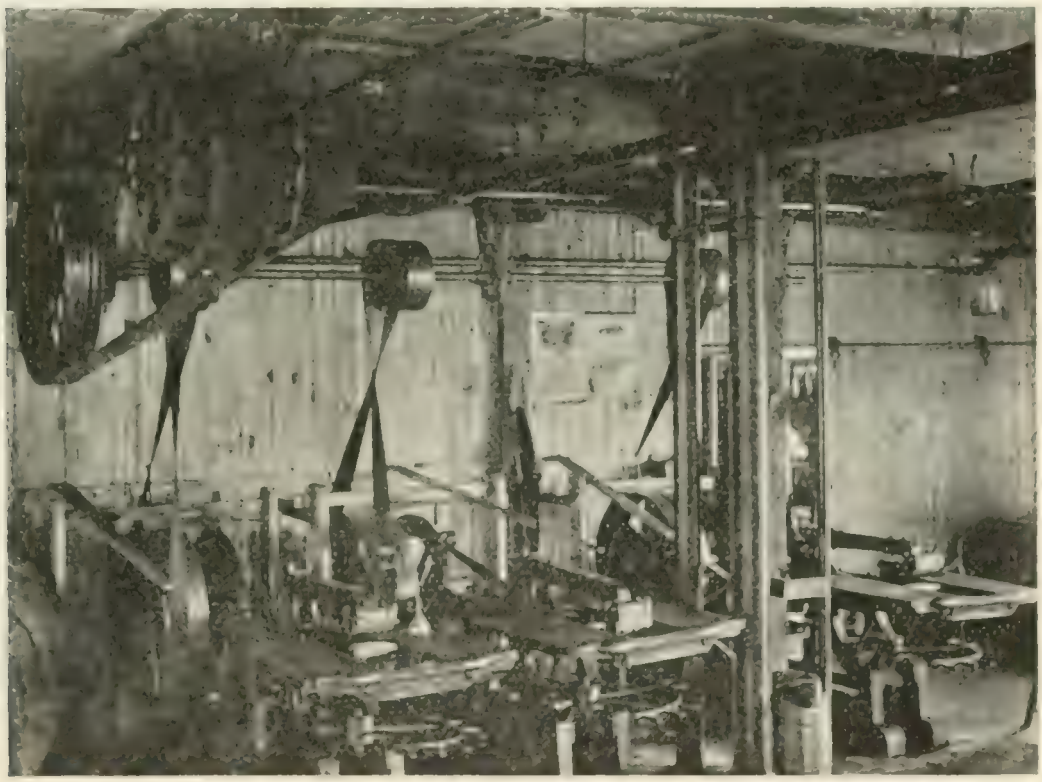


FIG. 5—SIX SLAKING MACHINES BELTED TO A 10 HORSE-POWER MOTOR

the moisture proof properties to the finished leather. The hides are now a pale blue color and are thrown into other paddle wheels for washing, following which they are passed to the shaving machines, where the hides are shaved on the flesh side, to give an even thickness and to remove the uneven surface which remains after the tanning process. The shaving machine, Fig. 3, consists of a group of cylindrical knives similar to those in the fleshing machine. The operator throws a hide on a rubber covered roll and by means of a foot lever presses the hide and the roll against the fast revolv-

ing blades. A six inch traversing emery wheel maintains a good cutting edge on the revolving spiral blades at all times.

The hides are next thrown into another pin wheel or color wheel, shown in Fig. 3, where they are permeated with the bluish coloring solution which gives the hide its first finished appearance. From the color wheels the hides are run through another set of putting-out machines to roll off the surplus coloring matter and stretch the hides. They are then hung on racks in a drying room, which is supplied by live steam coils as well as with exhaust heat from the floors below by means of the circulating fans shown in Fig. 4, which draw the air through galvanized iron ducts having inlets on each floor. The drying process requires several hours time,

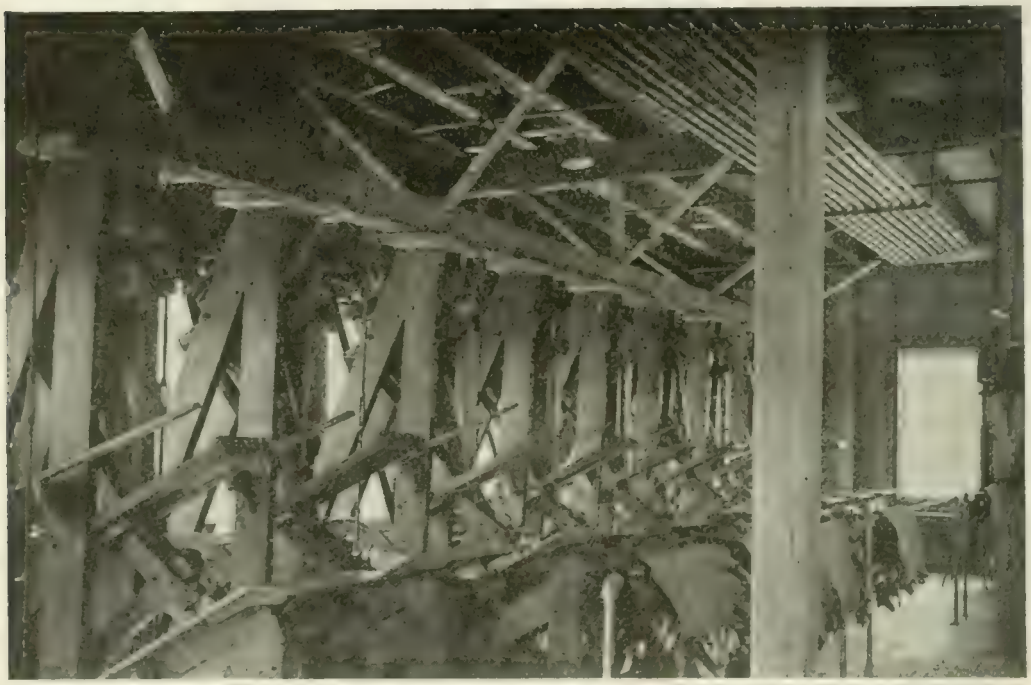


FIG. 6.—GROUP OF GLAZING MACHINES DRIVEN BY A 10 HORSE-POWER MOTOR

usually over night, during which time the steam pressure is from 35 to 50 lbs. on the boiler gauge.

The Finishing Department—From the drying rooms the hides are passed through the staking machines, Fig. 5, which scrape the flesh side of the hide and render the stiff and crumpled leather very smooth and pliable. A coating of black oil dressing is then applied to the face of the leather and it is sent to an auxiliary drying room to dry, after which the hides pass to the buffing room where the flesh side is smoothed off on emery faced wheels. Another application of oil dressing is next given, followed by another drying and ironing with the electric irons. The hides are then sent

down to the glazing room where they are passed through the side glazing machines, dressed again and dried. Each glazing machine has a reciprocating arm carrying a glass tool about two and one-half inches in diameter, which is drawn under pressure over the dull piece of leather thereby giving it a glossy appearance. From the glazing room the hides go again to the finishing room where every piece is passed through the measuring machine, Fig. 7,



FIG. 7—LEATHER MEASURING MACHINE BELTED TO A $\frac{1}{4}$ HORSE-POWER MOTOR

A 10 horse-power motor in the background is belted to a group of stakers, and another 10 horse-power motor on the left is belted through the wall to a group of buffing wheels. The measuring machine consists of a group of rollers which are lifted by the hide in passing through, thus actuating the dial hand at the top of the machine.

and carefully inspected previous to wrapping in bundles for shipment.

All the motors used in this installation are of the squirrel cage type, and motors five horse-power and above are equipped with oil-immersed auto-transformers with no-voltage and overload release attachment. These motors have been operated in the acid laden atmosphere of the plant with entirely satisfactory results. A list of the motors and their applications is given in Table I.

TABLE 1—DATA ON APPLICATION OF MOTORS

MACHINE	DESCRIPTION	MOTOR	
		HP	R.P.M.
Pump	Triplex plunger, 6 inch diameter, 8 inch stroke	15	1 155
3 Fleshing Machines	Used in cutting flesh from hides, bladed roll 7 inch diam. x 52 inch wide, 1625 r.p.m. Fluted roll 7 inch diam. x 52 inch wide, 38 r.p.m. Flywheel 16 inch diam. x 2⅜ inch x 1¾ inch rim	10	1 155
5 Pin Wheels	8 foot diam. x 3 feet 4 inches, face, used in washing hides in cold water baths	20	860
3 Pin Wheels	8 foot diam. x 3 feet 4 inches face, used in washing and pickling hides, 18 r.p.m.	15	865
Large Double Paddle Wheel	Paddle 4 feet diam. x 5 feet 5 inches face; vat 12 feet long x 8 feet wide, 4 feet 7 inches deep, skins circulated in chrome solution	3	1 150
2 Large Double Paddle Wheels	Size same as above		
4 Small Double Paddle Wheels	Paddle 4 feet diam. x 4 feet 6 inches face, 18 r.p.m.; vat 10 feet long, 8 feet wide, 4 feet 4 inches deep	10	1 155
3 Putting-out Machines	(a) 1 apron, 2 revolving rolls, spiral knives, 7 inches diam., 5 feet long, 165 r.p.m. (b) 4 apons, 5 feet x 2 feet each, 100 r.p.m. (c) Duplicate of (a)	15	1 155
1 Ventilating Fan	Used in exhausting acid fumes from tan house, 40 inch fan exhausting into open air	3	1 700
2 Shaving Machines	Bladed roll, 12 inches wide 6 inches diam., 3054 r.p.m. 6 inch traversing emery wheel used in keeping edge on bladed roll; revolving blade roll shaves off clinging flesh and uneven surface remaining on hides after tanning process	5	1 740
4 Pin Wheels	8 inches diam., 5 feet face, 18 r.p.m., used in coloring hides	10	870
2 Putting-out Machines	One apron each, two 1 inch x 5 inch spiral blades on each machine; hides are put out through these machines after passing through color wheels	10	1 155
4 Side Glazers 162 r.p.m. 1 Side Glazer 126 r.p.m. 1 Rolling Machine 90 r.p.m.	These machines have reciprocating arm on which is mounted a glass tool 2½ inches diam. which is drawn over the dull piece of leather, giving it a glossy appearance	5	1 130
9 Glazing Wheels	Machines perform the same operation as described above	10	1 120
Elevator	3 000 lbs. 55 feet per minute chain drive to special squirrel cage elevator motor.	8	720
6 Electric Irons	Used in ironing out skins in finishing process. These irons operate 110 volt, single-phase requiring 8.4 emperes each.		
3 Stakers 2 Stakers 1 Vaughn Table	Horizontal tables, 78 r.p.m. Inclined tables, 88 r.p.m Inclined tables, 90 r.p.m. The stakers scrape flesh side of hide after it has been dried.	10	850
2 Buffing Wheels	Emery faced, 24 inch diam. 7 inch face, 950 r.p.m.		
2 Buffing Wheels	Emery faced, 36 inch diam. 8 inch face, 850 r.p.m.	10	1 700
1 Exhaust Fan	20 inch diam. 8 inch fan, 1 230 r.p.m., 9 inch round suction, 8 inch square exhaust to open air		
Leather Measuring Machine	Measures area of skins in square inches, 84 r.p.m.	¼	1 140
Compound Ventilating Fan	60 inch fan used in connection with dry room	5	1 700
Compound Ventilating Fan	60 inch fan used in connection with dry room	5	1 700

SPEED CONTROL OF FANS AND BLOWERS

COMPARATIVE COSTS FOR DIFFERENT METHODS

W. E. THAU

THE three general methods of controlling the speed of fan and blower motors are, *a*—field control; *b*—armature control; *c*—combined field and armature control. A different type of motor is required for each method of control, that is, the same motor cannot be used in the three ways for a given fan. The results of elaborate tests show that the power required to drive centrifugal fans varies approximately as the cube of the fan speeds. The curves in Fig. 1 show these variations, while the curves in Fig. 2 show the control losses with change in speed by each method, based on an assumption that the loss in the field control resistance is zero. This assumption is nearly true, making method *a* the most economical and very satisfactory within the operating limits of the motor. The objection to using field control over a wide range of speed is the high cost of a suitable motor.

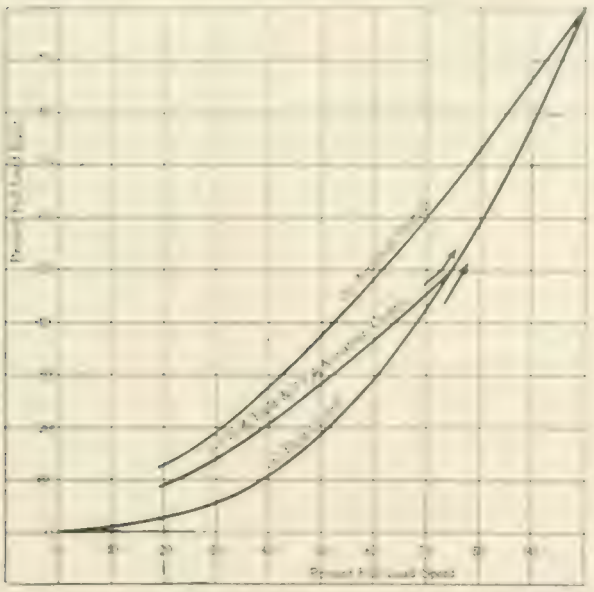


FIG. 1—CURVES SHOWING PERCENT OF FULL-LOAD INPUT TO MOTOR DRIVING A CENTRIFUGAL FAN AT VARIOUS PERCENTS OF FULL-LOAD SPEED

a—Field control; *b*—armature control; *c*—25 percent field control and 75 percent armature control.

Method *b* is more wasteful in most cases. The rheostatic losses increase very rapidly as the speed is reduced, reaching maximum at approximately 57 percent of maximum speed. Ordinarily, these losses do not exceed 20 percent of the motor input. It should be noted that this loss is much less with fans and blowers than in constant torque service where the rheostatic losses with armature control are directly proportional to the speed reduction.

Method *c* is a combination, the motor operating at full speed with weakened shunt field. The speed is reduced to 75 percent of full-load speed in this case by strengthening the shunt field, and from this point by armature control.

Curve *c*, Fig. 2, therefore follows curve *a* from 100 percent to 75 percent of full speed and then takes a form similar to curve *b*. The maximum loss by this method does not exceed ten percent of the motor input and occurs at approximately 45 percent of maximum speed.

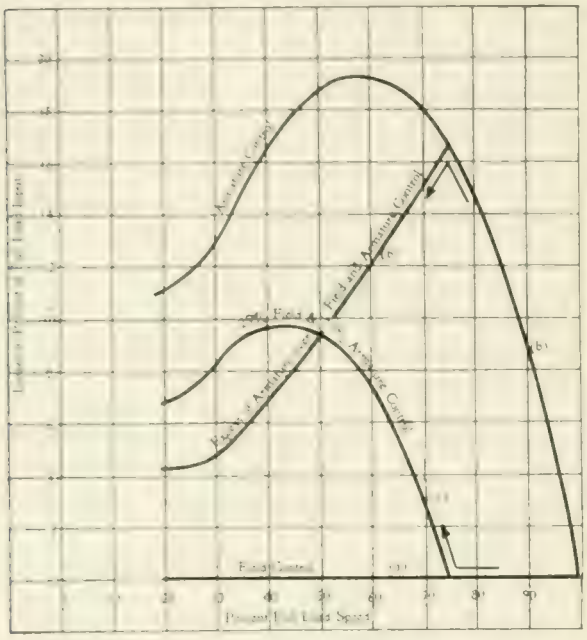


FIG. 2—CONTROL LOSSES
Based on an assumption that the loss in the field control resistance is zero.

Fig. 3 shows the cost of power per year to operate a motor requiring 10-kilowatt input at maximum speed, working 10 hours per day, 365 days per year, with energy at one cent per kilowatt-hour. The total cost of energy for any similar installation is directly proportional to the maximum input, the duration of operation, and the rate for energy.

For example, suppose a ventilating fan requires 25 horse-power at maximum speed and is to be operated at 20 percent reduced speed for 8 hours out of every 24. At 86.5 percent full-load efficiency the full-load input to the motor is 21.6 kilowatts. A ten-kilowatt outfit at 80 percent speed shows costs of $215 and $265, respectively (Curves *a* and *b*, Fig. 3), for 10 hours per day with one cent energy. To operate the 25 horse-power outfit 8 hours per day with energy at the same rate would therefore cost approximately $215 × (21.6 ÷ 10) × (8 ÷ 10) = $372 per year by field control, and $458 per year by armature con-

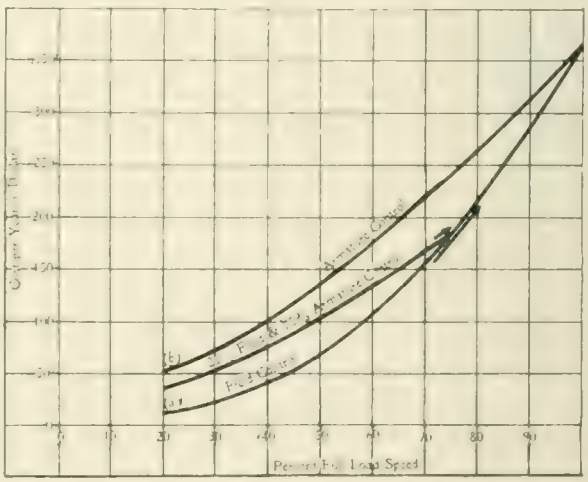


FIG. 3—COST IN DOLLARS PER YEAR TO OPERATE A TEN KILOWATT (INPUT) MOTOR DRIVING A CENTRIFUGAL FAN AT VARIOUS PERCENTAGES OF FULL-LOAD SPEED, TEN HOURS PER DAY
a—Field control; *b*—armature control; *c*—25 percent field control and 75 percent armature control. Cost of power taken at one cent per kilowatt-hour.

trol. These costs should be multiplied by the rate for any given locality. In any case, for this speed reduction the calculations will probably show that the saving in power cost will in a few months equal the increased cost of a suitable motor for field control over one for armature control. In a like manner comparisons can be made of costs of energy for operating a fan requiring any power at any speed reduction, by the three methods, and for any time and rate. By tabulating calculations for any given system, comparing costs of motors and cost of energy, the most economical method of speed control will be clearly indicated.

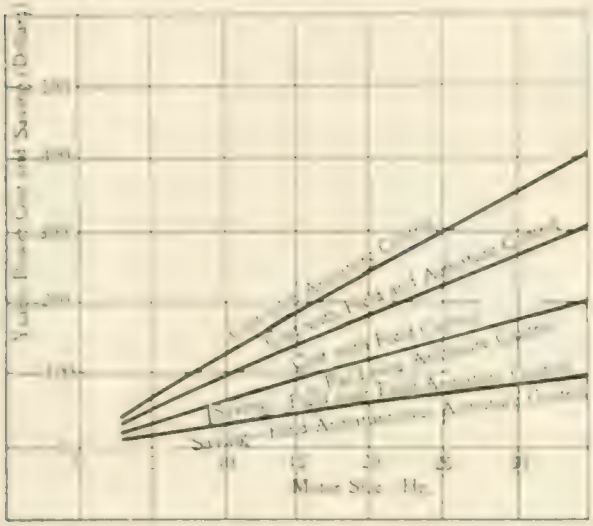


FIG. 4—CURVES SHOWING YEARLY POWER COST AND SAVINGS FOR MOTORS UP TO 35 HORSE-POWER, DRIVING CENTRIFUGAL FANS

Motors running ten hours per day at 50 percent speed. Cost of power taken at one cent per kilowatt-hour.

Figs. 4, 5 and 6 show annual cost of energy at a one cent rate for operating fans requiring from 3 to 35 horse-power at speeds of 50, 70 and 80 percent of maximum by each method of control.

Where the motor operates for long intervals at speeds between 50 and 100 percent of maximum speed, the field control shows the best economy. If the motor operates for long intervals at speeds between 75 and 100 percent of maximum speed, but is occasionally required to operate at speeds below 75 percent, the combination control gives the best economy. For

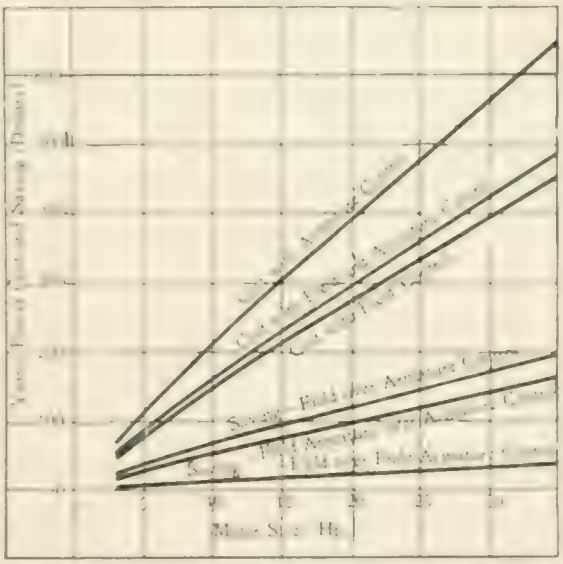


FIG. 5—CURVES SHOWING YEARLY POWER COST AND SAVINGS FOR MOTORS UP TO 35 HORSE-POWER, DRIVING CENTRIFUGAL FANS

Motors running ten hours per day at 70 percent speed. Cost of power taken at one cent per kilowatt-hour.

motors operating for long intervals near maximum speed, but which also operate occasionally at lower speeds, the armature control shows the best economy. If the motor is to operate only at or near

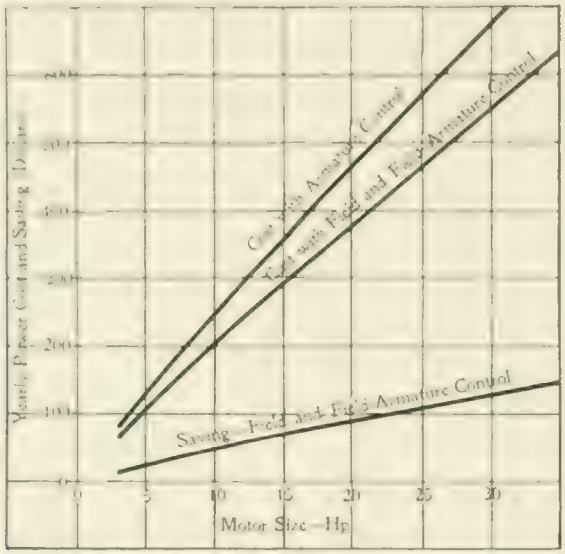


FIG. 6—CURVES SHOWING YEARLY POWER COST AND SAVINGS FOR MOTORS UP TO 35 HORSE-POWER, DRIVING CENTRIPUGAL FANS

Motors running ten hours per day at 80 percent speed. Cost of power taken at one cent per kilowatt-hour.

maximum speed the ordinary motor will be sufficient, because all shunt motors are capable of giving some speed change by field variation.

AUTOMOBILE ENGINE TESTING BY ELECTRIC MOTORS

A. G. CHAPIN

At the time when automobiles first became commercially successful, about 1900, and for the next few years, gasoline automobiles were manufactured in a somewhat haphazard and uneconomical way. Previous to 1904, no definite and reliable method of testing automobile engines had been employed, and many engine imperfections were not discovered until the cars were in service, when it was necessary to return them to the factory and have the engines dismantled and repaired, or altered while in the chassis, resulting in heavy expense as well as loss of future business. In such testing as was done, friction brakes or large fans were used to absorb the energy delivered by the engines. All the power was wasted and accurate measurements of the output of each engine were well-nigh impossible.

Early in 1905, a generator was built for the Stevens-Duryea Company, according to the designs of their engineer, with the end-bells extended to ball-bearing pedestals and the entire field frame balanced, thereby constructing a dynamometer. It was equipped with a brake-beam, switching apparatus, meters, and a rheostat of sufficient capacity to absorb the entire load. Development of this outfit was carried far enough to prove that from a practical standpoint it was not commercially feasible, particularly where a number of such outfits would be required. Feeding power back into the line was practically impossible except when all the engines under test were operating at the same speed and load, a condition rarely existing in any large automobile plant, and even at the best this pumping back could be accomplished only at the expense of constant attention and careful manipulation. In addition to these disadvantages, there must be considered the initial cost of the dynamometer, which is sufficient to prohibit its use when compared to the direct-current coupled motor drive.

A second design was developed consisting of a 17.5 kilowatt, 550 volt, compound-wound, 1 200 r.p.m. direct-current machine coupled through two universal joints to each gas engine.

The operation of the equipment is as follows:—

The engine is placed on the testing blocks and coupled to the

motor. The operator closes a switch which cuts in resistance giving the motor one-quarter speed and operating it as a shunt-wound machine, with no gas or spark on the engine. This operation is continued for about five hours, during which time the engine bearings, valves, valve gears and pistons become properly broken in and aligned, plenty of high-grade gas engine oil being supplied during the run to facilitate operation. The second step consists of another five-hour run, during which time the engine is supplied with gasoline and spark and run at from one-half to full speed, with the coupled motor simply running idle with switches open. This test gives an opportunity for proper setting of the carbureter, adjusting of the spark and general observation of the action of the engine.

During the third portion of the test, the engine is started by the motor, but immediately upon receiving its gas and spark relieves the motor of its load, the switches being opened at this point. When the engine is brought up to 1 200 r.p.m. the motor then becomes a generator and is built up to 550 volts, at which point the main and equalizer switches of the generator are closed, allowing it to feed back into the direct-current supply circuit, operating as a compound-wound machine. The gas and spark on the engine are then advanced steadily until the engine is operating under its full load, still at 1 200 r.p.m. At the end of five hours it is usually found necessary to take up the engine bearings and make minor adjustments, after which the engine is subjected to another short full-load run at 1 200 r.p.m.

In order to take care of the output of the factory, eighteen of these test motors or generators were installed on the testing floor. An eighteen panel switchboard is used to control the sets, each panel being equipped with one carbon break circuit-breaker, two single-pole, double-throw knife switches, one single-pole, single-throw equalizer switch, one four-point voltmeter receptacle and one differential ammeter. On a bracket at the end of the board is an illuminated dial, direct-current differential voltmeter. Each panel also has as part of its equipment a grid resistance designed to give one-quarter and one-half speeds by the use of the double-throw switches, when the machines are operating as motors. At any time, the operator can obtain an accurate reading of the load on any individual engine by the use of its respective ammeter on the panel and the voltmeter. An efficiency chart is provided for each machine, which is posted in a conspicuous place for use during tests.

In addition to this equipment, a large motor-generator set was installed, consisting of a three-phase, 60 cycle, 440 volt induction motor mounted on the same shaft with a 550 volt, compound-wound, direct-current generator of sufficient capacity to take care of all of the factory requirements. An equalizer lead runs from this machine to the 18-panel board, and connects to each one of the equalizer switches. This allows the current generated by the testing sets to be sent back over the factory circuit and put to useful work. This complete equipment has been in daily operation successfully for the past six years.

Since the development and installation of this outfit testing engineers have come to the conclusion that still more satisfactory operation could be obtained in the following manner:—

First, that the individual testing sets be 220-volt, direct-current, compound-wound machines, equipped with commutating poles, which will eliminate the sparking caused by changing the machines from motors to generators, without any manipulation of the brushholder rigging. By means of the adjustable speed characteristics, engines can be tested at widely different speeds.

Second, that a synchronous motor-generator set or rotary converter be installed in the place of the present induction motor-generator set. Recently this company has completed a change from direct-current to alternating-current motors throughout its shops with the exception of three elevator motors. (This change to alternating-current motors does not of course apply to the testing outfits). As a consequence of this, it would be possible and practicable to operate the synchronous motor-generator set, or the rotary converter, inverted, when taking current from the 17.5-kilowatt testing sets as generators, transforming the current generated by the testing outfits to alternating-current and using it in the factory circuit to good advantage, and furthermore raising the power-factor of the line.

The 440-volt current supplied to the alternating-current end of the large induction motor-generator set above referred to is received from the company's own turbine plant, so in this particular instance power-factor correction by the use of synchronous machines is especially to be desired. With an alternating-current supply from central station lines, operation would be just the same as in the present case, although power-factor correction would not be of so vital importance to the manufacturer.

Another simple and economical method, which, however, lacks the advantage of adjustable speed but which does away with the necessity for a motor-generator set or synchronous converter, is to belt an induction motor to each gas engine. The induction motor is started in the regular way by means of an auto-starter. When the engine develops its full output it will run the motor as an induction generator at a speed slightly above synchronism. The energy supplied to the line will be equal to the brake horsepower of the engine minus the losses in the motor. Engines of different speeds can be tested by changing pulleys.

Direct-current motors can be used to even greater advantage, where the energy supply is suitable. The motor with the connected engine can be started in the usual way, the speed adjusted to a point just below that at which the engine is to run, after which the engine can be made to take its load by driving the motor as a generator.

It would be possible with any of these schemes to place a graphic meter on each generator panel and thus be able to supply load charts when necessary. While it might be of advantage to have one panel so equipped for the testing of a new model engine, the expense of putting graphic meters on each panel for the testing of the standard factory output would be rather large. For all practical purposes of automobile engine testing, the readings of the differential ammeter and voltmeter, used in connection with the efficiency charts, give all that is required. That two gas engines of the same model brought through the factory at the same time and, under exactly similar conditions, will not test out alike by sometimes as much as several horse-power is a well-known fact that should be considered in determining the advisability of using a graphic meter on each panel in addition to the ammeter and voltmeter.

Developments of industrial engineering problems in the last few years have proven, without question, that individual drive is the only adequate solution of such a problem as the one here considered. With individual drive, engines can be tested at any desired speed by selecting suitable motors for connection through universal joints or by changing pulleys if the drive is by belt. If it is necessary to test some engines at higher speeds than others, adjustable speed machines may be used to good advantage.

NOTES ON THE APPLICATION OF SMALL INDUCTION MOTORS

BERNARD LESTER

WITH the wide-spread use of small split-phase induction motors for driving the large variety of machines in the home, office and store, the correct application of these motors becomes of considerable importance. Small motors of this type are often installed where abnormal overload conditions can easily exist and are operated usually by those who know little or nothing about the care of machinery. Furthermore, no protective device which can be used to protect the motor from injurious overload appears to be commercially feasible. Obviously it is to the material benefit of central station, motor manufacturer, and individual users to see that motors are applied correctly and with due regard, not only to the *average* working conditions, but to the *abnormal* working conditions, in order that their operation may be satisfactory in every respect. Such features as high power-factor and efficiency, which are important points to consider in large induction motors, are of comparatively minor importance in small split-phase induction motors, since the amount of power consumed by the motor is very small. Features of starting torque, pull-out torque, or maximum torque, heating, and in some instances starting current, are, however, of prime importance.

A typical performance curve of a small split-phase induction motor is shown in Fig. 1. This represents the performance of the motor without centrifugal clutch. From the curve it may be seen that the starting torque is equal to full-load torque. It is possible to wind the motor so as to produce a starting torque higher than full-load torque, although a centrifugal clutch is usually employed where high starting torque is necessary.

It is of course important to see that the motor selected has sufficient starting torque to bring the machine to be driven up to speed promptly. It is far more important, however, to see that the value of starting torque is sufficient to bring the machine up to speed promptly when conditions are abnormal. Two points that must particularly be borne in mind are, first, possible conditions requiring an abnormal starting torque, and second, possible conditions of the supply circuit which may prevent the motor from delivering its rated torque when starting.

Consider, for instance, the case of the portable electric drill equipped with a split-phase induction motor. The motor is usually started before the drill spindle is placed in contact with the material to be drilled, and the motor has only to bring up to speed the train of gears and the spindle itself. It sometimes happens, however, particularly in the hands of an inexperienced operator, that the drill will be forced into the metal with such pressure as to stall it, or it may become stuck by the carelessness of the operator in improperly holding the drill. Thus a starting torque much greater than that normally required may be necessary to bring the motor up to its rated speed again.

The torque developed by a motor at starting varies as the square of the voltage impressed upon it. Rated voltage may not be obtained in the motor due to insufficient transformer capacity, or light wiring from transformer to motor. Furthermore, a single-phase induction motor takes a greater current when starting than when running under normal load, which of course increases the drop in voltage at the moment of start. These factors emphasize the necessity of providing a liberal margin of safety between the amount of starting torque developed by the motor and that required to bring the machine up to speed.

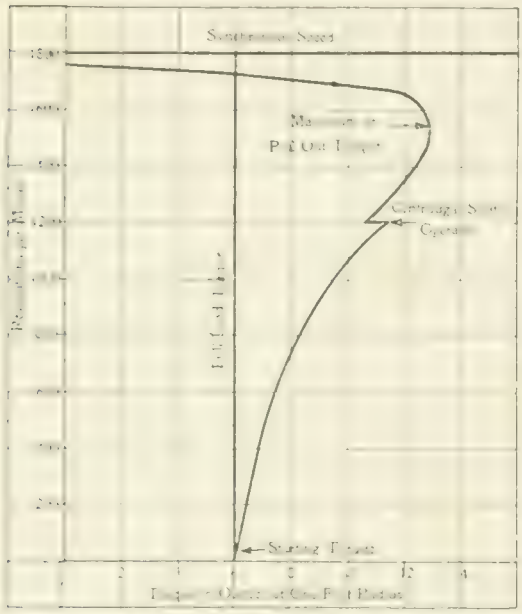


FIG. 1—TYPICAL PERFORMANCE CURVE OF SMALL SINGLE-PHASE INDUCTION MOTOR, WITHOUT CENTRIFUGAL CLUTCH

One-eighth horse-power, 110 volts, 60 cycles, four poles. Centrifugal switch cuts out starting winding at about two-thirds speed.

The feature of pull-out or maximum torque is of great importance, particularly where there is a variable load, and the emergency conditions should be considered. A motor-driven mangle in the hands of some inexperienced operator may stall, if equipped with a motor of insufficient pull-out or maximum torque and, unless the motor is disconnected from the power circuit the current will of course overheat it and eventually the motor will burn out. In some motor-driven adding machines a momentary heavy torque load is

placed on the motor at very rare intervals by the operation of a certain combination of levers or keys. Obviously the pull-out torque developed by the motor must be sufficient to take care of such rare overloads in torque. Points such as these have led to a careful analysis of the factors of starting torque and pull-out torque in applying small motors. These values are usually measured in ounces. The diagram, Fig. 4, and following explanation, will be found of service to those having much to do with the application of split-phase induction motors of small sizes.

INSTRUCTIONS FOR THE USE OF DIAGRAM

Knowing the horse-power and speed at full load to determine full-load torque: for example, find the full-load torque of a ¾ hp motor running 1 700 r.p.m. at full load (1 800 r.p.m. synchronous speed). Find the intersection of the vertical line through 1 700 r.p.m. with the curve marked ¾ hp (560 watts), and horizontally opposite this intersection at the left is the torque 36.5 oz.



FIG. 2—MOTOR DRIVEN PORTABLE GRINDER OR DRILL

The starting torque and maximum running torque can be found by multiplying the full load torque by the proper constants. For example, if the starting torque of this particular motor is 1.5 times the full-load torque, its value is $1.5 \times 36.5 = 55$ oz. Likewise if the maximum running torque of the motor is 2.5 times the full-load torque, its value is $2.5 \times 36.5 = 91$ oz. These constants must be determined from the characteristic curves of the individual motor.

The horse-power at maximum torque can also be determined from the curve if the speed is known. For approximate results the slip of small split-phase induction motors at maximum torque can be taken at 25 percent. In the case of the above motor the speed at maximum torque will therefore be approximately 1 350 r.p.m. Find the intersection of the vertical line through

1 350 r.p.m. with the horizontal line through 91 (oz. torque). This is near the line representing 1.5 hp, which is the approximate power developed by the motor just before pulling out, or stalling.

Knowing the *horse power* and *efficiency* to find the *true watts;* for example, assume that the efficiency of the ¾ hp motor is 75 percent. Find the intersection of the vertical line through 75 with the ¾ hp curve and horizontally across from this intersection is 746 watts.

Knowing the *true watts input*, the *power-factor* and the *voltage* to find the *current per phase* (or per terminal); for example, as-

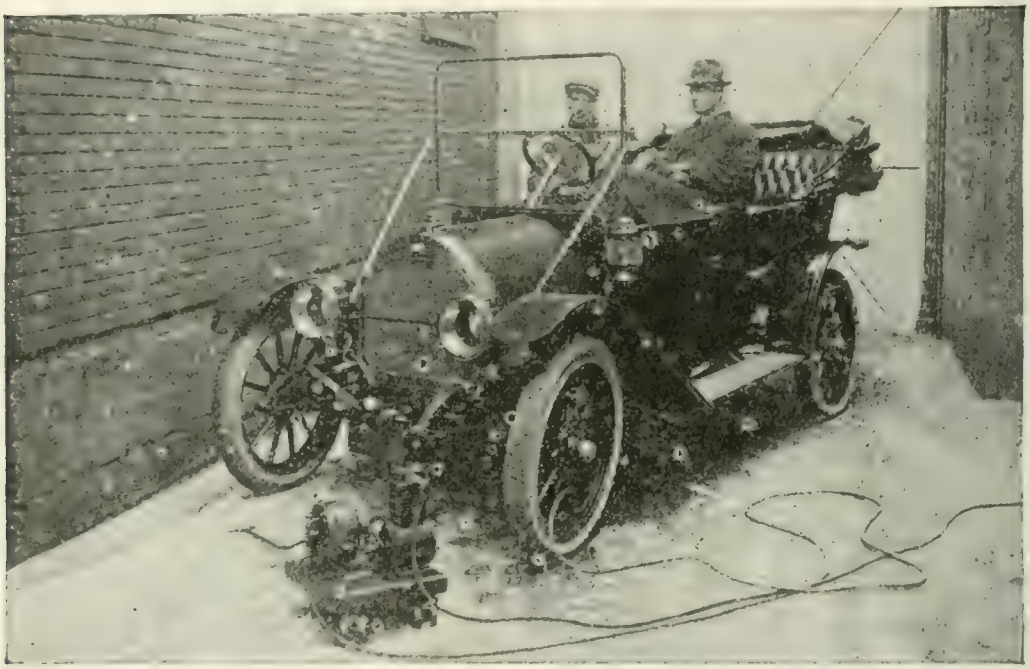


FIG. 3—PUMPING TIRES WITH PORTABLE MOTOR-DRIVEN GARAGE PUMP

sume that the power-factor of the foregoing motor is 70 percent and the voltage 220 volts. Locate the intersection of the 70 percent power-factor vertical line with the diagonal representing 746 watts. The horizontal line passing approximately through this point represents 1 050 watts apparent. Then from the intersection of the vertical line representing 220 volts with the diagonal representing 1 050 watts, the horizontal line representing amperes is determined, namely 4.8 amperes, single-phase, or 2.8 amperes three-phase. The current per terminal in a two-phase motor is one-half that for a single-phase motor, and in this case would be 2.4 amperes.

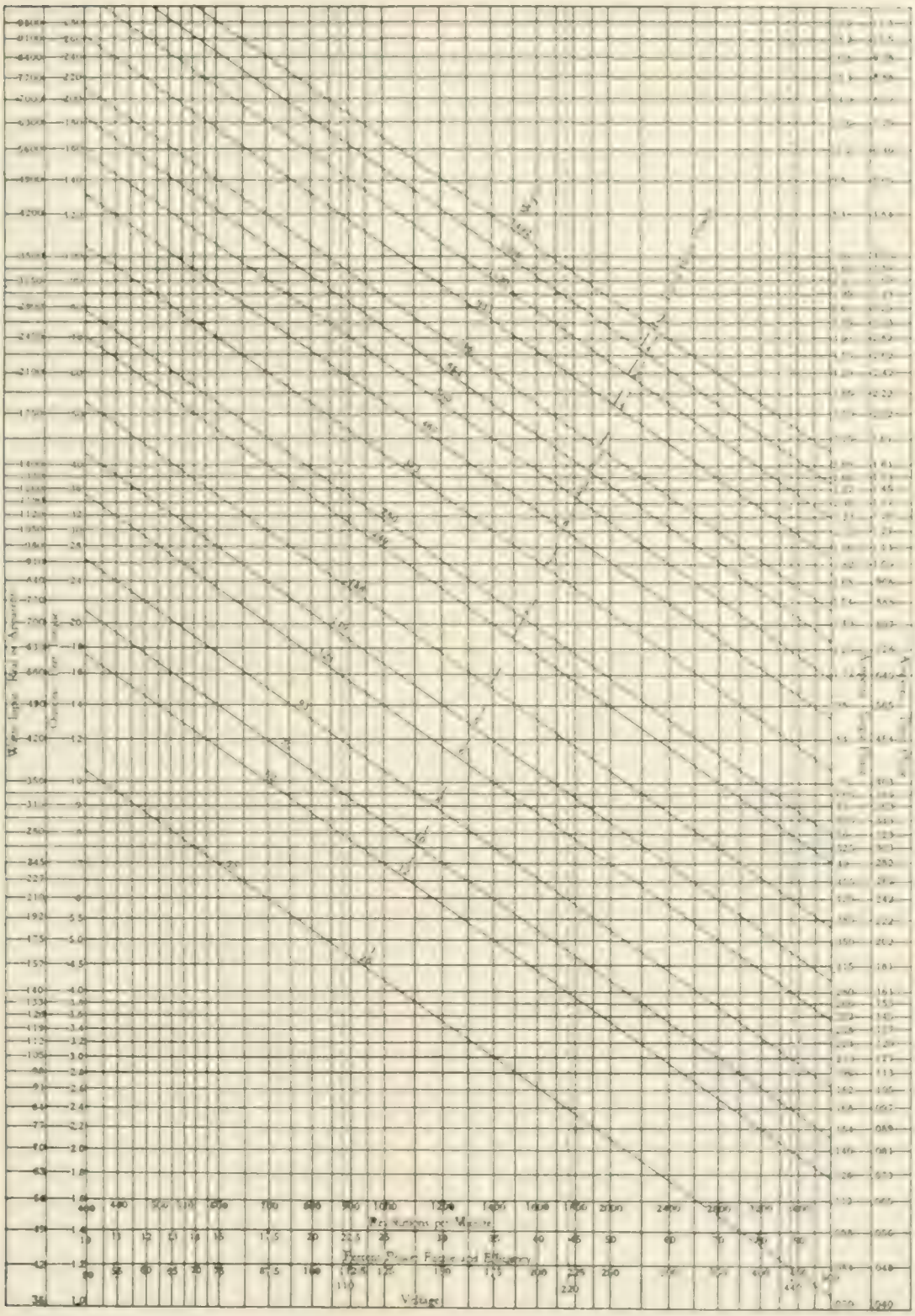


FIG. 4—CHART FOR DETERMINING RELATIVE CHARACTERISTICS OF SMALL INDUCTION MOTORS

For current in two-phase motors, take half the value indicated for single-phase motors.

VENTILATION OF A BITUMINOUS COAL MINE

G. W. HAMILTON

AS the ventilation of a mine depends on such conditions as the nature of the seam, whether gaseous, or non-gaseous; the thickness of the coal; the kind of top, or roof; the output to be secured, now, and in the future; the total number of men employed in each pair of entries, or headings; and the total number of men employed in the mine, this subject becomes a question for individual consideration in each case. A plan view of a small bituminous drift mine, such as is frequently found throughout the South Central portion of Pennsylvania, and commonly known as a single panel mine, is shown in Fig. 1. The direction of the air used for ventilation, may be traced by noting the arrows shown along the several entries, or headings, and rooms.

One method of attack is to investigate the state laws on ventilation, and ascertain what must be done to comply with them. On doing this for a Pennsylvania mine the following items are encountered:—

1—In a non-gaseous mine 150 cubic feet of free air per minute must be furnished for each person employed. If explosive gas can be detected in the mine by an approved safety lamp, the amount must be increased to 200 cubic feet of free air per minute at minimum. For horses or mules, not less than 500 cubic feet of free air per minute should be furnished per animal.

2—The main current of air must be split, or sub-divided, so as to give a separate current of reasonably fresh air, to every 70 men at work.

3—The ventilating fan must be kept in operation continuously day and night, unless work at the mine has been definitely suspended.

4—No main ventilating fan may be placed inside of the mine.

5—Every ventilating fan must be equipped with a recording instrument to register the revolutions of the fan, or its air pressure, from day to day.

6—If a fan be used inside of the mine it must be run by electricity, or compressed air.

The mine outlined in Fig. 1 is a small non-gaseous, soft coal, drift mine, which would have about 80 men at work, under normal conditions, and, because of its size, the direction of the air may be

taken care of by self-closing doors between the cross entries. Should the mine be of larger capacity, employing, say, 160 men at one time, the main air current would have to be split at least twice, if not three times, and the air from each split served must be conducted to the main return air course through an "overcast" or "undercast," an air-tight air-way made over, or under, the main intake. Whenever practicable an overcast is made, as the undercast is liable to collect water, dirt, etc.

As the general rules relating to ventilation will be unchanged, they are given in this article with reference to the mine shown in Fig. 1. The fan, in this case, is located near the outcrop of the

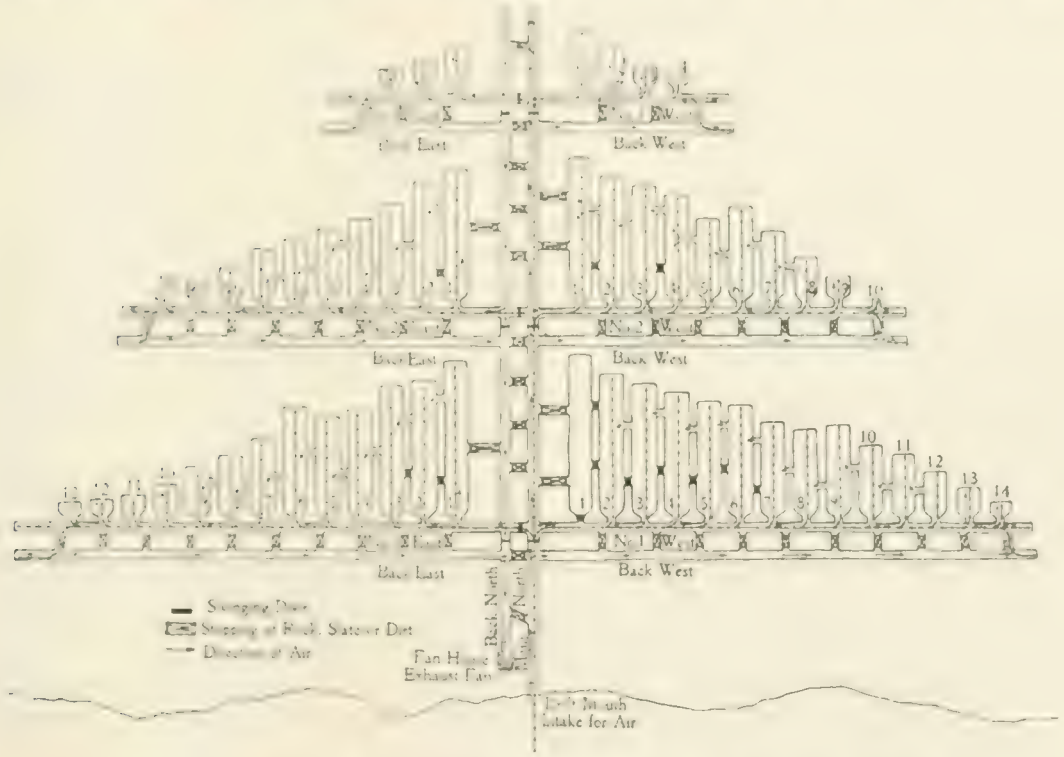


FIG. 1—OUTLINE OF A SMALL PENNSYLVANIA SOFT COAL MINE

Main North Back Entry, and is being operated as an exhaust fan. This makes the *Main North Entry* the intake for the air, the plan being to keep all the entries and rooms, between the intake and the fan, as if in one continuous tunnel.

When the fresh air enters the mine at the drift mouth, it is drawn along the *Main North Entry*, as indicated by the arrows, until it strikes the self-closing door shown between the *No. 1 West* and the *No. 1 Back West*, and being unable to make headway in this direction, turns into the *No. 1 Back West* and follows this route until it strikes the coal at the face. As it cannot proceed

further to the West, in turns through the only cross-cut which is open, into *No. 1 West* and travels toward the *Main North Entry*, a part of its volume going into the rooms. On reaching the *Main North* it is forced to turn to the right, because of the door in the cross-cut between the *Main* and *Back North Entries*, and soon reaches *No. 2 Back West* into which it turns, and proceeds as outlined before, in *No. 1 Back West*, and *No. 1 West* This course is followed until the air finally turns into the *Back North Entry*, outside of the *No. 1 Back East*, and is discharged by the fan.

On the basis of eighty men and two mules at work, the output being gathered and hauled by electric locomotives, the following items should be considered:—

1—Eighty men at 150 cubic feet of free air per minute; two mules at 500 cubic feet per minute.
2—Minimum dimension of entries, or headings, 4 ft. 6 in. high by 6 ft. wide.
3—Total length of entries, or air-course, 12 000 ft.
4—Velocity of the air to be about 600 ft. per minute.

The main points to be considered will be as follows:—

1—80 men × 150 cubic ft.=12 000 cubic ft. Two mules at 500 cubic ft. = 1 000 cubic feet. Total 13 000 cubic feet of free air per minute.
2—"Perimeter" of air-course, or, the length of the polygon bounding its cross section,=2 (4.5+6)=21 feet.
3—The rubbing surface, or the perimeter of the air-course, × the length of the air-course, = 21×12 000=252 000 sq. ft.
4—The Sectional Area of the air-course, or the area of its cross section =4.5×6=27 sq. ft.
5—The Co-efficient of friction, or the resistance offered to the air in the air-course, by a unit area of rubbing surface, at a velocity of one foot per minute. (The co-efficients generally used are, 0.000 000 0217 (Atkinson); and 0.000 000 01 (Fairly). The latter in low seams, 6 feet and under).
6—The Quantity of Air in circulation per minute, or the sectional area of the air-course × the velocity of the air = 27×600=16 200 cubic feet per minute.*
7—The unit of ventilating pressure in lbs. per sq. ft., or the co-efficient of friction × the rubbing surface of airway × the velocity of the air current squared and ÷ the sectional area = $\frac{0.000\,000\,01\times 252\,000\times 600^2}{27}$ = 33.6 lbs. per sq. ft.
8—The units of work or power per min. in ft. lbs., or the unit of ventilating pressure × the sectional area × the velocity of the air = 33.6× 27×600=544 320 ft. lbs., per minute.
9—The power applied to the air or the total units of work, ÷33 000=$\frac{544\,320}{33\,000}$=16.5 horse-power.

*If the velocity of air be reduced to 530 ft. per min., the quantity of air circulated will be 14 300 cubic ft. per min., which will be a minimum amount if 10 percent be allowed for leakage and other losses.

These are the main items in connection with an estimate on the amount of air required in a mine, as shown in the plan, also on the amount of power required to drive fans supplying this air. In determining the motive power to drive a mine fan, due allowance should be made for the efficiency of the fan, in addition to the above indicated power required for driving the air. This fan information should preferably be obtained from the manufacturer, and in general it is expected to be approximately 50 to 60 percent.

In a non-gaseous mine the speed of the air may range from 600 to 1 500 ft. per minute, but his will be governed by the conditions inside, as there is not much value in an air current in which a man cannot keep, or hold, a light with his lamp. A great deal also depends on the general conditions of the mine, together with the undeveloped work to be done in the future. Provision should usually be made for future growth and also for speeding up the fan in case of emergencies, such as a partial stoppage of the entries by an accident

From these points it will be seen that while there are set rules by which the volume of air required to ventilate a mine may be determined, the securing of the information on which these rules must depend becomes a question of mine inspection for present conditions, and a knowledge of he plan of the workings laid out for future conditions.

DIRECT-CURRENT BALANCER SETS

A. C. LANIER

WITH the extension of areas served by central stations distributing energy for lighting and power purposes, the questions of copper economy without sacrifice of voltage regulation early emphasized the necessity of higher operating voltages. The inherent low voltage characteristics of commercial lamps, however, as well as questions of safety to the consumer, fixed the voltage at the receiving end within rather narrow limits. In alternating-current systems the problem offered an easy solution through the use of transformers for receiving mains; in direct-current systems resort to multi-wire circuits became necessary.

With a given amount of energy to be delivered to the receivers at a specified voltage drop, the feeders and mains of a direct-current system can be reduced to one-half the original weight by doubling the line voltage; with the same percentage drop in voltage, to one-fourth the weight. With a given receiver voltage, less than the desired transmission voltage, the result could be accomplished by grouping the load units in series pairs, as in Fig. 2. The disadvantage of this arrangement is the necessity of operating lamps in pairs, or else cutting in an equivalent resistance when any lamp of a pair is disconnected from the circuit. By connecting a third wire to the mid point of the pairs of lamps, as in Fig. 3, individual units are independent; and if equality in the total effective resistance on the two sides of this "neutral" wire is maintained, the voltage will remain closely balanced, local currents flowing along the neutral as indicated by the arrows. Obviously, since the same volume of current flows through the lamps on each side of the neutral, any inequality in effective resistance will result in a proportional voltage unbalance. Since electrical apparatus in general, and the incandescent lamp in particular, will not operate satisfactorily with widely fluctuating impressed voltage, such a system must provide for artificial maintenance of voltage balance with varying conditions of load distribution.

In a three-wire system, with double the voltage between outers of the corresponding two-wire circuit, using a neutral of one-half the section of the outer wires, the copper weight, for the same voltage drop in the outers is five-eighths of that of the two-wire systems; while with the same percentage drop, it is reduced to five-

sixteenths. For five and seven-wire circuits proportionally greater savings are obtained. Economies here indicated have led to the wide use of multi-wire circuits—three-wire generally, five and seven-wire in some instances.

A few of the more important methods* employed to maintain voltage balance in the direct-current multi-wire circuits are indicated here.

TWO-WIRE GENERATORS IN SERIES

In early installations, two generators connected in series between the outers, with the neutral wire tapped to their common



FIG. 1

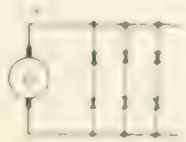


FIG. 2



FIG. 3

junction point, as in Fig. 4, were much used. Generators were shunt or compound-wound, each supplying the load required on its side of the neutral, and regulating inherently or by hand for its varying load.

THREE-WIRE GENERATOR

The three-wire generator finds frequent application in isolated plants and small stations. Several designs, differing in the method

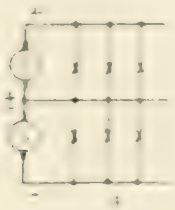


FIG. 4



FIG. 5

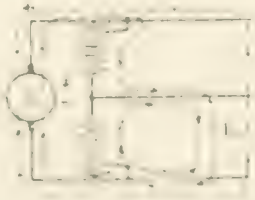


FIG. 6

of obtaining the neutral of the armature, have been built. The most successful form of three-wire machine consists essentially of a standard two-wire generator, wound for the voltage required across the outers, from the armature of which taps are brought out to collector rings, Fig. 5; the reactance or "balance" coil *A* is con-

*A number of articles have been published on this subject, among them:
"On Direct-Current Balancers," by A. E. Kennelly and S. E. Whiting. *Electrical World*, January 7, 1905.
"Regulation and Compounding of Lighting Balancers," by Budd Frankenfield. *Electrical World*, December 23, 1905.
"Direct-Current Compensators for Balancing Electric Circuits," by H. M. Biebel, *Western Electrician*, February 23, 1907.

nected through brushes to the slip rings, and the neutral wire is tapped to the mid point of the balance coil. With symmetrical armature taps, the point A, on balanced load, is the neutral of the system; slight inequalities in voltage on unbalanced load are the result of Ir drop due to unbalanced currents in the armature, leads, collectors, and balance coil. A two-phase connection gives somewhat better distribution of unbalanced currents in the armature of the generator with corresponding improvement in voltage regulation. Balance coils generally provide for ten percent unbalance, although greater percentages are often specified.

TWO-WIRE GENERATOR WITH AUXILIARY BALANCING APPARATUS

Storage Battery—A storage battery connected across the terminal busses of a two-wire generator is shown in Fig. 6, with the mid point of the battery joined to the neutral wire. Ordinarily end cells or boosters or both are used to secure closer adjustment of voltage balance. On balanced load the battery floats across the

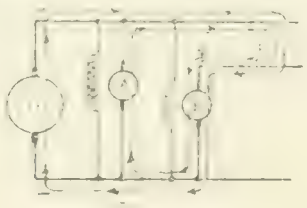


FIG. 7

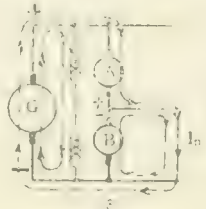


FIG. 8

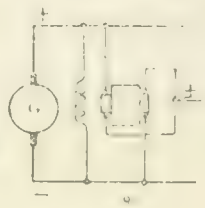
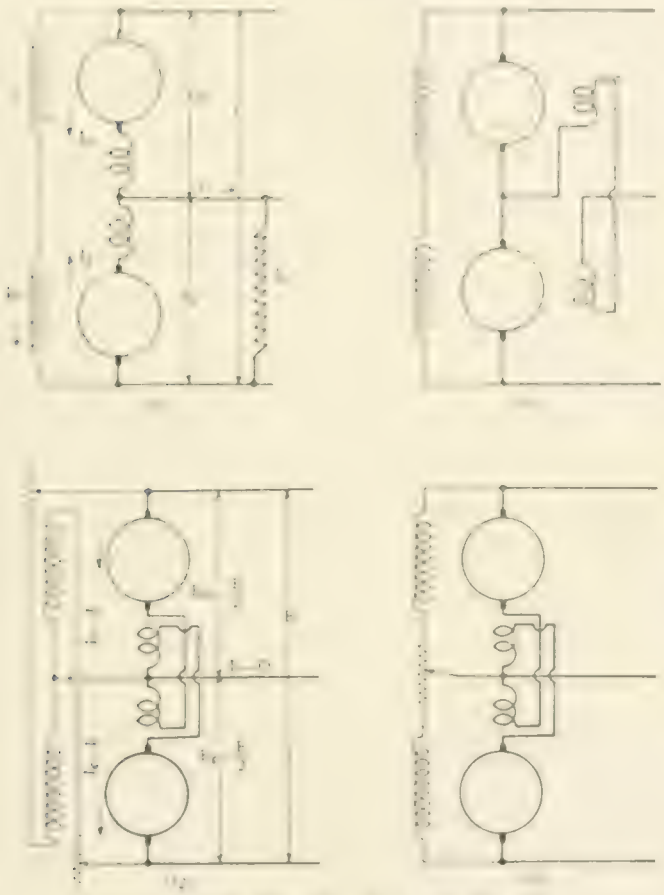


FIG. 9

line; with excess load, as Ir, on one side of the neutral, the battery on this side discharges, while that on the more lightly loaded side is charged, the combined charge and discharge currents flowing through the neutral wire and supplying the unbalanced current. The neutral voltage shifts by the amount necessary to allow the required charge and discharge currents to flow. Voltage can be adjusted by cutting in end cells on the discharge and cutting them out on the charging half of the battery, or inherently through the proper form of booster. The battery may serve in addition for the regulation of the main generator voltage and output.

Motor-Generator Balancers—A more satisfactory class of auxiliary equipment for the usual application is found in the motor-generator balancer. Several of its commercial forms are illustrated schematically in Figs. 7 to 13. The armatures of the two units composing the set shown in Fig. 7 are rigidly connected; one is wound for the voltage of the main generator, the other for one-half or any desired fraction of that voltage. Each unit must have a capacity equal to the maximum unbalanced energy required plus the losses (except those of the shunt fields) of the set. With bal-

anced load the set runs light across the line, each unit acting as a motor without external load. With excess load between the neutral and the negative main, *B* supplies unbalanced current to the neutral wire at half voltage; *A* acts as driving motor, drawing its power from the main generator. With shift of load to the other side of the neutral, *B* acts as a motor at half voltage and drives *A* as a generator at full outer voltage; the current components supplied by the main generator and *A* combine to supply the required unbalanced current, the component from the main generator exceeding that from *A* by an amount necessary to supply, at the voltage of the motor *B*, the armature losses of the set. The dashed line and arrows in Fig. 7 indicate the current flow; shunt fields are shown excited by the main generator direct.



FIGS. 10, 11, 12 AND 13

A modification of the equipment in Fig. 7 is indicated in Fig. 8; each of the units composing the set is approximately one-half the capacity of those just described, with armatures rigidly connected and wound usually for one-half the line voltage. With balanced load the motors run light across the line. With unbalanced load between the neutral and the negative main, *B* acts as a generator, *A* as a motor, the combined current supplying the excess in load required, that in *A* exceeding that in B by the current component of the armature losses of the set at half voltage; current flow is indicated by dashed lines and arrows. The equipment is inherently reversible with shift of unbalanced load from one side of the neutral to the other. Fig 8 gives the connection for a shunt wound balancer; such equipments are more frequently compound wound with various schemes of connections as shown in Figs. 10 to 13.

A dynamotor, Fig. 9, may replace the motor-generator set for service as a rotary balancer; since the two armature windings rotate in the same magnetic field, however, independent voltage regulation or adjustment cannot be obtained. The dynamotor is smaller and more compact than the motor-generator, but is more difficult to repair and does not permit of the adaptation of standard generators for such equipments.

SHUNT WOUND BALANCERS

Two identical shunt machines, with armatures wound for half main generator voltage and rigidly connected, may serve as a rotary balancer. On balanced load the set runs light as two shunt motors in series; the current input of the armatures supplies the rotational losses of the machines, mechanical and magnetic friction and I^2r losses in the armature. With the scheme of connections indicated in Fig. 8, the two armatures revolve in magnetic fields of equal strength, and generate equal counter e.m.f.'s., the set attaining such speed that the sum of these two counter e.m.f.'s plus the armature Ir drop equals the pressure across the mains. On load the combined magnetomotive forces of main field and armature result in a decrease in effective field flux; this decrease being practically equal for both motor and generator action, the counter e.m.f.'s of the two units remain sensibly constant and equal on all loads within the operating range, the speed of the set varying inherently with load.

The balancer action of the motor-generator set with an unbalanced load condition between neutral and outers, results from a decrease in voltage on the side of the neutral having greater current demand, i. e., of lower effective resistance, and a corresponding increase in voltage on the opposite side. The counter e.m.f.'s in the two units of the set remaining constant, less motor current will flow through the armature connected across the heavier loaded side and more through that across the lighter, the algebraic sum of the currents in the two armatures supplying through the neutral wire, the unbalanced current required. Should this voltage unbalance reduce the terminal pressure of one unit below its counter e.m.f., the direction of current flow in its armature is reversed; its action becomes that of a generator driven by the other unit as a motor, the combined currents of motor and generator supplying the unbalanced demand. The current and the armature Ir drop of the motor exceed those of the generator by an amount proportional to the armature losses of the set.

Voltage Regulation

Let E, E_m, E_g = Voltage across outers, across motor and generator terminals respectively.

e_l, e_m, e_g = Induced voltage running light, and under load as motor and generator respectively.

e_l, e_{bm}, e_{bg} = Voltage drop across brushes running light, and under load as motor and generator respectively.

I_l, I_m, I_g, I_a = Amperes, armature running light, motor armature, generator armature, and in neutral wire respectively.

r_a = Armature resistance.

ϕ, ϕ_m, ϕ_g = Flux in maxwells entering armature per pole, running light, and under load as motor and as generator respectively.

R_l, R = Speed in r.p.m. running light and under load.

p, p_l = Pairs of poles per machine, pairs armature circuits.

N_a = Number armature surface conductors.

$$E = e_l + I_l r_a + e_{bl} \quad \cdots \quad (1)$$

$$e_l = E - (I_l r_a + e_{bl})$$

$$= p \phi_l \times \frac{N_a}{p'} \times \frac{R_l}{60} \times 10^{-8} \quad \cdots \quad (2)$$

For unbalanced load, the set supplying unbalanced current, with equal and constant excitation on both machines as indicated in Fig. 8,

$$E_m = e_m = \left[I_m r_a - e_{bm} \right] \quad \cdots \quad (3)$$

$$e_m = p\phi_m \times \frac{N_a}{p'} \times \frac{R}{60} \times 10^{-8}$$

$$R = \frac{6 e_m \times 10^8}{p \frac{N_a}{p'} \phi_m} \quad \cdots \quad (4)$$

$$E_g = e_g = \left[I_g r_a - e_{bg} \right] \quad (5)$$

$$R = \frac{6 e_g 10^8}{p \frac{N_a}{p'} \phi_g} \quad (6)$$

With close approximation $\phi_m = \phi_g$ and $e_m = e_g = e_l$, the full-load speed R increasing as the fluxes ϕ_m and ϕ_g decrease.

$$\frac{R}{R_l} = \frac{\phi_l}{\phi_g} = \frac{\phi_l}{\phi_m}, \text{ approximately}$$

Substituting value of e_l in equations (3) and (5)

$$e_l = E_m - \left[I_m r_a + e_{bm} \right] \quad \cdots \quad (7)$$

$$= E_g + \left[I_g r_a + e_{bg} \right] \quad \cdots \quad (8)$$

$$E_m = E_g + \left[I_m + I_g \right] r_a + e_{bm} + e_{bg}$$

$$E = E_m + E_g = 2E_g + r_a \left[I_m + I_g \right] + e_{bm} + e_{bg}$$

$$E_g = \frac{E}{2} - \frac{I_n r_a}{2} + \frac{e_{bm} + e_{bg}}{2} \qquad (9)$$

$$E_m = \frac{E}{2} + \frac{I_n r_a}{2} + \frac{e_{bm} + e_{bg}}{2} \qquad (10)$$

where $I_n = I_m + I_g$

If, in Fig. 8 the mid point of the shunt field is connected to the neutral wire the shunt excitation of the two machines no longer remains equal, that of the generator becoming weaker and of the motor stronger with increasing unbalance in load. The voltage regulation is therefore poorer. By crossing the shunt fields, Fig. 14, so that the generator field is connected on the motor side of the neutral and vice versa, the regulation is better than indicated in the above analysis. This connection of fields should be used with shunt balancers, and where hand regulation is feasible a three-point box connected at *c* will permit adjustment of voltage for any load.

The graphical method offers a simple solution for voltage division and speed change with load of the shunt wound balancer.

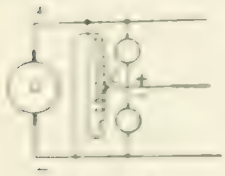


FIG. 14

In Fig. 15 the construction for shunt field connections shown in Fig. 8 is indicated; the construction given is not to scale. Ordinates represent speed of set in r.p.m., and abscissae, volts; the voltage scale of the machine acting as motor measures from left to right, for the unit acting as a generator, right to left. The light dash lines represent induced volt-speed curves of both the units at no load; they intersect at the half voltage point of the system. The running light armature *Ir* drop added to the induced volts for each induced volt-speed curve gives, with the same voltage intersection, the true no-load speed of the set, indicated by the light full line. If no field weakening occurred on load, the full load volt-speed curve would be obtained by adding to the no-load induced volt-speed curve of the motor the full load motor *Ir* drop in the armature, and by subtracting the full-load generator *Ir* drop from the generator no-load induced volt-speed curve; the intersection of these curves would give the voltage division on load. (See dot and dash line.) Since the net field fluxes of generator and motor are less on load than at no load, a load induced volt-speed curve for each unit (not indicated in Fig. 15) must be calculated, and the

terminal volt-speed curve of each machine obtained from it as indicated above. It is apparent that the full-load speed of the set is higher than that at no load.

Solutions for the other cases mentioned, the mid point of the shunt fields connected to the neutral wire, with fields either straight or crossed, are readily obtained by the same method.* Obviously the field excitation does not remain constant in these cases, but is proportional either to that of the unit considered or to the other machine of the set. Best inherent voltage regulation and least increase in speed from no load to full load is obtained with shunt fields crossed.



Fig. 15

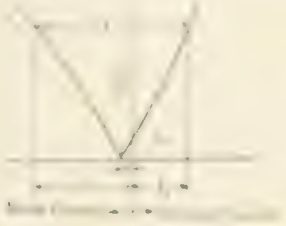


Fig. 16

Current Division between Motor and Generator.—Let L_m, L_g = total losses (except shunt fields) of motor and generator respectively. W_m, W_g = friction, windage, and iron losses of motor and generator respectively.

With unbalanced current I_n in neutral wire,

$$I_n = I_m + I_g \quad \cdots \quad (11)$$

With balanced load $I_n = 0$

$$I_m = -I_g = I_l \quad \cdots \quad (12)$$

Since the units of the balancer set are operating practically as separately excited machines, the motor armature output equals, for any value of neutral current, the generator armature input, i. e.,

$$E_m I_m - L_m = E_g I_g + L_g \quad \cdots \quad (13)$$

Where $L_m = I_m^2 r_a + I_m e_{fm} + W_m$

And $L_g = I_g^2 r_a + I_g e_{fg} + W_g$

A ready method of determining current division between motor and generator is given in Mr. Frankenfield's paper. Values of wattage outputs of motor armature and wattage inputs of generator armature are calculated with assumed values of I_m and I_g. Motor and generator currents as ordinates are plotted against watts as abscissæ as indicated in Fig. 16, motor currents being measured

*For fuller discussion of the graphical solution for shunt-wound balancers see Mr. Frankenfield's paper, "Regulation and Compounding of Lighting Balancers."

to the left and generator currents to the right of the axis of abscissae. For any required neutral current I_n, represented by the horizontal distance between the two curves, the corresponding values of I_m and I_g can be obtained.

COMPOUND-WOUND BALANCERS

The compound-wound balancer generally consists, in its usual form, of two identical compound machines, the armature wound for half the main generator voltage (if equal voltage division is desired), rigidly coupled mechanically, and connected in series electrically. In the assumption of load with unbalancing in the external circuit, the field fluxes in the two units do not remain practically equal as in the shunt balancer. The series field of the motor opposes, while that of the generator assists, its shunt field; the field flux of the motor and therefore the induced e.m.f. in this armature are decreased, and those of the generator increased by amounts corresponding approximately, for flat compounding, to the internal Ir drops in the two machines, with the result that practically an equal division of total voltage is maintained between the neutral of the set and the two outer wires within the normal operating range of the set. Over-compounding can be secured, if desired, within limits imposed by requirements of stability. From causes, in the main covered in the discussion of shunt balancers, the speed of the set rises with increasing load.

With the series field of each unit connected in the circuit of its armature, as indicated in Fig. 10, the machines of the set operate, on balanced load, as differential motors in series, running light. On load, the decrease of field flux in the motor exceeds the increase in the generator, since the current in the motor series field is greater and, due to the lower magnetic density in the magnetic circuit of the motor, relatively more effective than in the generator; these causes may lead to excessive speed rise and to instability on overload. With series fields connected in the circuit of the neutral wire, as in Fig. 11, the units of the set, on balanced load, run light as shunt motors in series. Under load the undivided neutral current flows through the series field of each machine, the motor flux is not weakened so much as in the case just discussed, also the flux and therefore braking action of the generator is stronger; the required induced e.m.f.'s to compensate for internal Ir drop and maintain balance in voltage can therefore be generated at a lower speed for

any given load, and the operation of the set is more stable. With series fields crossed, as indicated in Figs. 12 and 13, the machines on balanced load run light as compound motors in series, the effect of the series field when running light in this case, as in that of Fig. 10, is practically negligible. Since, when operating as motor-generator on unbalanced load, the generator series field is connected in series with the armature of the motor unit, the cumulative compounding of its field is stronger than the differential action of the motor field whose series coils are connected in the circuit of the generator armature. The effect is similar to that indicated above in the discussion of Fig. 11, but more marked: the burden of compounding is shifted somewhat from motor to generator; there is less rise in speed with increasing load than in either of the other connections shown, a decreased tendency to instability and, with other conditions constant, a corresponding increase in the safe momentary overload capacity. With shunt fields tied to the neutral (Figs. 12 and 13) rheostatic adjustment of voltage balance is available; two frequently used methods of disposing shunt field rheostats are shown. Obviously other combinations of shunt and series field connections are available.

Voltage Regulation. In addition to the symbols used in the shunt balancer analysis:—

Let r_s = Resistance of series fields in ohms.

$100\ p_c$ = Percent overcompounding referred to balanced voltage, $\frac{E}{2}$.

For balanced load, set running light;—

$$E = 2e_1 + 2I_1 (r_a + r_s) + 2e_b \qquad (14)^*$$

$$e_1 = \frac{E}{2} - [I_1 (r_a + r_s) + e_b]$$

For balanced load, set supplying unbalanced current to neutral wire;—

Motor induced e. m. f., $e_m = E_m - [I_m (r_a + r_s) + e_{bm}]$ (15)*

Generator induced e. m. f., $e_g = E_g + [I_g (r_a + r_s) + e_{bg}]$ (16)*

Relations developed in equations (4) and (6) apply to compound balancers

$$\text{Since, } E = E_m + E_g$$

$$\text{For flat compound } E_m = E_g = \frac{E}{2} \qquad (17)$$

For overcompounding, $100\ p_c$

*Equations 14, 15 and 16 apply to balancers with fields connected in series with the armature, the slight changes in the form of the equations where the series fields are connected in the neutral circuit are obvious.

$$E_g = \frac{E}{2}(1 + p_c)$$

$$E_m = \frac{E}{2}(1 - p_c)$$

$$E_g = E_m\left(\frac{1 + p_c}{1 - p_c}\right) \quad - - - - - \quad (18)$$

$$E_m = E_g\left(\frac{1 - p_c}{1 + p_c}\right) \quad - - - \quad (19)$$

The required full-load series field ampere-turns for flat or any desired compounding can be determined for any of the three cases shown in Figs. 10, 11, 12 and 13 by the following construction.*

Using equations (4), (6), (15) and (16), speeds, R, are calculated for full-load motor and generator induced e.m.f.'s, e_m and e_g, for several net values of motor and generator field fluxes, ϕ_m and ϕ_g. Values of gross ampere turns corresponding to each value of ϕ_m and ϕ_g can be obtained from the magnetization curve of the machines, field weakening due to armature distortion being taken into account. With equal values of the shunt ampere-turns in motor and generator, as would be the case in flat compounding, the series ampere-turns of motor and generator corresponding to each speed can be obtained from equations (20) and (21):—

$$N i_{sg} = N i_g - N i_{sh} \quad - - - - - \quad (20)$$

$$N i_{sm} = N i_{sh} - N i_m \quad - - - - - \quad (21)$$

Where, $N i_{sg}$ = Generator series ampere-turns full load.

$N i_{sm}$ = Motor series ampere-turns full load.

$N i_{sh}$ = Motor and generator shunt ampere turns.

$N i_g$ = Generator total ampere turns full load.

$N i_m$ = Motor total ampere turns full load.

In Fig. 17 the values of series ampere-turns obtained above are plotted as abscissae against speeds as ordinates, in the full line curve. The point of intersection of the motor and generator curves *A*, gives full-load speed and series ampere-turns for equal series ampere turns in the motor and generator, i. e., series fields connected in the neutral (see Fig. 11); the intercepts *Bm* and *Bg* with the horizontal above the intersection of the curves measured in the

*A similar though somewhat less direct determination of one case, the series fields connected in the neutral, is given in Mr. Frankenfield's paper above mentioned.

proportion of motor to generator current, give values for the series fields connected each in series with its own armature (see Fig. 101); and similar intercepts below the horizontal C_m and C_g, for series fields crossed over (see Figs. 12 and 13). For flat compounding the full-load performance is obviously independent of shunt field connections. The influence of the method of connecting series fields in the balancer circuit, upon the rise in speed from no load to full load, as shown by the speed intercepts on the full line curve in Fig. 17, is a fair index of the relative stability under operating conditions. On overload the differences in speeds and stability are more marked.

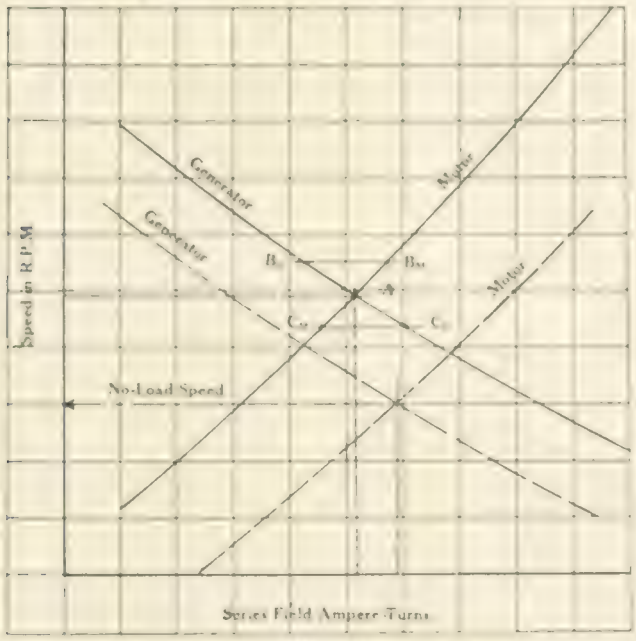


FIG. 17

With shunt fields crossed the inequalities in voltage division at loads between no load and full load, exact adjustment at those two points assumed, are practically negligible in sets of moderate or large capacity; with shunt fields connected straight and tapped to the neutral, the variations of voltage curves from a straight line is usually very slight. The general character of the voltage regulation curve and the amount of variation from the straight line which might be obtained in a very small

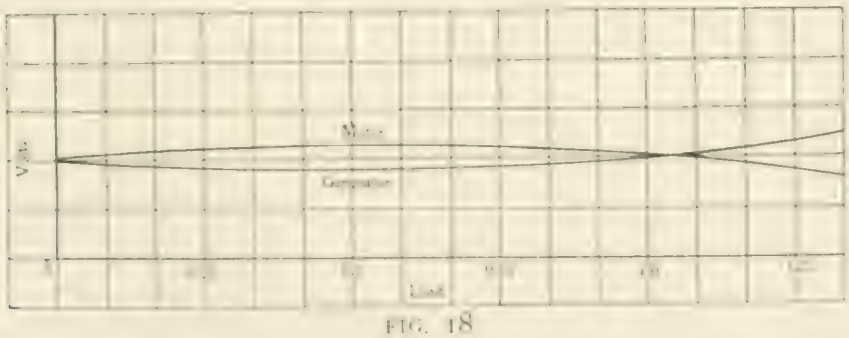


FIG. 18

set is indicated in Fig. 18. The calculated and test results for a 400 ampere balancer over the same load range shows in general no appreciable departure from the straight line.

Division of Current Between Motor and Generator—

From equations (11) and (13)

$$I_m = \frac{E_g}{E_m} I_g + \frac{L_m - L_g}{E_m}$$

$$= I_n - I_g$$

Where $L_m = I_m^2 (r_a + r_s) + I_m e_{bm} + W_m$

$$L_g = I_g^2 (r_a + r_s) + I_g e_{bg} + W_g$$

$$I_g = \frac{I_n - \frac{L_m + L_g}{E}}{1 + \frac{E_g}{E_m}} \quad - - - - - \quad (22)$$

$$I_m = \frac{I_n + \frac{L_m + L_g}{E}}{1 + \frac{E_m}{E_g}} \quad - - - - - \quad (23)$$

This becomes for flat compounding;—

$$I_g = \frac{I_n}{2} - \frac{L_m + L_g}{E} \quad - - - - \quad (24)$$

$$I_m = \frac{I_n}{2} + \frac{L_m + L_g}{E} \quad - - - - \quad (25)$$

For over-compounding, 100 p_c percent, substituting equation (18) and (19) in (22) and (23)

$$I_g = \frac{I_n}{2} (1 - p_c) - \frac{L_m + L_g}{E} \quad - - - \quad (24a)$$

$$I_m = \frac{I_n}{2} (1 + p_c) + \frac{L_m + L_g}{E} \quad - - - \quad (25a)$$

Where motor and generator efficiencies are available, the following approximate equations for flat compounding are sometimes used:—

$$I_g = I_n \frac{\mathcal{E}_m \mathcal{E}_g}{1 + \mathcal{E}_m \mathcal{E}_g} \quad - - - - - \quad (26)*$$

$$I_m = I_n \frac{1}{1 + \mathcal{E}_m \mathcal{E}_g} \quad - - - - - \quad (27)*$$

Since equations (26) and (27) include shunt field losses, the value of *Ig* from (26) is slightly smaller than from (24) and *Im* from (27) slightly larger than from (25). For example, in a balancer set of 200 ampere capacity, with normal full-load efficiency,

*"Regulation and Compounding of Light Balancers," by Frankenfield.

the division of current between motor and generator on full neutral load will be approximately,—

From (24) and (25) I_m = 113 amperes 50.5 percent of neutral
I_g = 87 amperes 43.5 percent of neutral
From (26) and (27) I_m = 115.3 amperes 57.6 percent of neutral
I_g = 84.7 amperes 42.4 percent of neutral

On partial loads the discrepancies are naturally larger.

The current division between motor and generator in percent of neutral current, will average about 42 percent generator, 58 percent motor; in very large sets, as slight differences as between 47 percent generator and 53 percent motor may be reached, while in very small sets the division will be more nearly 38 percent generator and 62 percent motor.

EFFICIENCY OF BALANCER SETS

Efficiency as motor generator set $\delta_B = \frac{\text{Set output}}{\text{Set input}}$

$$= \frac{E_g \; I_g}{E_m \; I_m + E_{shm} \; I_{shm} + E_{shg} \; I_{shg}} \quad - - - - \quad (28)$$

Where δ_B, δ_m, δ_g = efficiencies of set, of motor and generator respectively
E_{shm}, E_{shg} = e.m.f. impressed on fields of motor and generator respectively
I_{shm}, I_{shg} = shunt field currents of motor and generator

For flat compounding at full load and approximately at other loads, $\frac{E}{2} = E_m = E_g$ and $I_{shm} = I_{shg} = I_{sh}$. Equation (28) reduced to

$$\delta_B = \frac{I_g}{I_m + 2I_{sh}} \quad - - - - \quad (29)$$

For over-compound, 100 p_c percent, equation (28) becomes

$$\delta_B = \frac{(1 + p_c) \; I_g}{(1 - p_c) \; I_m + 2I_{sh}} \quad - - - - \quad (29a)$$

when the shunt fields are in series across the outers, and with close approximation for other shunt field connections.

Obviously the motor-generator efficiency of the balancer set gives an unfair, or at least an incomplete statement of the economy with which such equipments handle the unbalanced load. It has been proposed that the balancer efficiency be expressed in terms of unbalanced power delivered to the external circuit, *Eq In*, and the increase in power demand upon the main generator or plant, $E\,(I_m + I_{sh})$, i. e.,

$$\mathcal{E}_B = \frac{E_g I_n}{E (I_m + I_{sh})} \quad \text{- - - - - - (30)}$$

In this equation a constant term, $E_g I_m$, of untransformed energy has been added to both numerator and denominator of the fraction expressing the ratio of energy transformation in the set. This hardly conforms to recognized conceptions of efficiency.

In order to give proper weight to balancer losses, the set should be considered in connection with the main generator, plant, or feeding system of which it forms a part. An obvious objection to such procedure lies in the necessity for arbitrary assumption as to

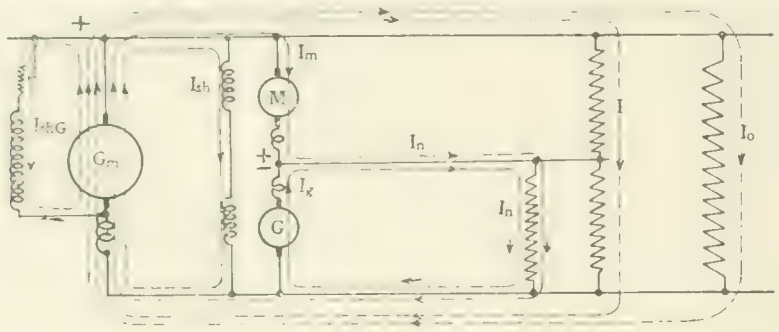


FIG. 19

relation between generator and balancer loading with varying total output. The simplest and probably best basis for estimating the performance is that of main generator and balancer both operating at full rated load. In general referring to Fig. 19, if,—

I_o = current in mains due to apparatus operating across the outers.

I = current of half voltage apparatus in lighter loaded main.

I_n = Unbalance current in the neutral wire.

I_m, I_g, I_{sh} = Full-load motor, generator and shunt field currents of balancer, then,

$$I_o + I + I_m + I_{sh}$$

output current of generator with balancer at full load.

Kw_1 = Full load input of generator.

L_g = Total losses in balancers at full load.

$\mathcal{E}_G$ = Main generator efficiency.

$\mathcal{E}_o$ = Over-all efficiency, including balancer.

Efficiency of generator alone,

$$\mathcal{E}_G = \frac{E (I_o + I + I_m + I_{sh})}{Kw_I} \quad \text{- - - - (31)}$$

Combined efficiency of generator and balancer,

$$\mathcal{E}_o = \frac{E (I_o + I) + I_n E_g}{Kw_I} \quad \text{- - - - - (32)}$$

For flat compounding,

$$\mathcal{E}_o = \frac{E\left(I_o + I - \frac{I_n}{2}\right)}{Kw_I} \qquad (33)$$

For overcompounding $(1 + P_c)$, $\mathcal{E}_o = \frac{E\left(I_o + I - \frac{I_n}{2}\left[1 + P_c\right]\right)}{Kw_I}$ (33a)

Introducing $\mathcal{E}_G$ into equation (33),

$$\mathcal{E}_o = \frac{I_o + I - \frac{I_n}{2}}{I_o + I + I_m + I_{sh}} \times \mathcal{E}_G$$

substituting value of I_m from equation (25)

$$\mathcal{E}_o = \frac{\left(I_o + I - \frac{I_n}{2}\right)\mathcal{E}_G}{I_o + I + \frac{I_n}{2}\left(\frac{L_m + L_g}{E} - I_{sh}\right)}$$

$$= \frac{\mathcal{E}_G}{1 + \frac{L_B}{E\left(I_o + I - \frac{I_n}{2}\right)}} \qquad (34)$$

Similarly, the combined efficiency, for overcompounding 100 p_c percent:

$$\mathcal{E}_o = \frac{\mathcal{E}_G}{1 + \frac{L_B}{E\left(I_o + I - \frac{I_n}{2}\left[1 + P_c\right]\right)}} \qquad (34a)$$

Obviously with no full voltage apparatus connected across the line, $I_o = O$.

For example, consider a 250 kilowatt, 250 volt generator installed with a balancer to take care of 20 percent unbalanced current in the neutral, a 200 ampere, 250/125 volt set being required, $I_o = O$.

Assume 92 percent full load efficiency of generator.

$I_m = 113$, $I_{sh} = 2.3$ amps.

$L_B = 3800$ watts.

$I + I_m + I_{sh} = 1000$ amps.

$I = 884.7$ amps.

Then on full load, $\mathcal{E}_o = \frac{0.92}{1 + \frac{3800}{250(884.7 + 100)}} = 90.6$

the plant efficiency being lowered 1.52 percent by use of balancer. If $I_o = 400$ amperes, a 120 ampere balancer would serve for the same total generator output, and the plant efficiency, assuming balancer losses of about 2600 watts, becomes 91.25 percent, a loss in efficiency of only 0.9 percent due to balancer.

On partial loads, even assuming that the balancer load decreased in proportion to main load, the effect upon plant efficiency would be more marked.

In large plants where the percentage of unbalanced load is small, the balancer losses lower only slightly the plant efficiency; while for a very small plant, the influence of such losses is more marked than suggested above.

COMMUTATION

Since the units composing a balancer set act alternately as motor and generator, the brushes on non-commutating pole machines are adjusted at approximately the no-load neutral position. Advantage can be taken of the commutating fringe from the main pole only in a limited way, and reliance must be placed largely upon resistance commutation. Brushes may be shifted slightly against rotation, giving to the motor, which carries the heavier armature current and has the weaker main field, a slight advantage in position. Machines designed for such service should have excellent commutating characteristics, or be proportionately under-rated.

The commutating pole machine lends itself particularly to this type of service. There is available at the point of commutation a flux, proportional, over a wide load range, to the current commutated, its value and direction is such as to give in general straight line reversal of current in the coils short circuited by the brushes, and its magnetizing current in series, and therefore,, in time phase with the armature current. Such machines can therefore work up to full rating of motor on the basis of heating.

STABILITY AND COMPOUNDING

Stable operation of compound-wound balancer sets, even where subject to sudden and heavy overloads, is obtainable if the units making up the set are designed for this service, and the proper field connections used. In general, the most stable performance results where there is the least change in quantity and distribution of motor field flux for the maintenance of balanced voltage with varying load. A low value of the armature and series field resistance and of main field flux distortion, requiring relatively small differential action in the motor fields and a small working range on the magnetization curve, are favorable. It is obviously desirable that the series fields be crossed, so that compounding takes place with minimum speed increase. (See Fig. 17.) The effect of armature distortion upon speed is suggested by a comparison of the dash and full line curves of Fig. 17; in the former, the weakening of the main field due to armature distortion is neglected, while in the latter this factor is taken into account.

Though balancers are ordinarily wound for flat compounding, yet where the set must be located at a considerable distance from the feeding point, over-compounding to compensate for feeder drop is desirable. The degree of over-compounding available is limited

by the stability of the set on overloads such as occur under service conditions. Reasonable over-compounding, about five percent, is readily obtainable in conservatively designed sets.

STARTING AND PARALLEL OPERATION.

In starting the balancer the shunt fields should be connected in series across the outers, with the mid point of the fields, c in Fig. 14, disconnected from the neutral of the set, and the armatures brought up to speed by use of a starting rheostat. With the armatures running light in series across the outer wires, the mid point of the neutral should be connected to the neutral point of the set, and rheostatic adjustment made for no-load voltage balance; the switch connecting the neutral of the set to the neutral wire of the distributing system should then be closed, and the balancer will inherently assume its load, maintaining the voltage balance. For voltage adjustment a field rheostat in each shunt field is sometimes specified, though a three-point box, as indicated in Fig. 13, is preferred; in compound-wound sets of moderate and small size, rheostats are frequently omitted. A single-pole switch is often used for disconnecting the mid point of the shunt fields from the neutral of the set in starting; a blank button on the three-point rheostat may answer, or a device for connecting the shunt field to neutral when the set is up to speed may be incorporated in the starting box.

Similar compound-wound balancers will operate satisfactorily in parallel, if proper interconnections are provided. When the series fields are connected in the neutral circuit, one equalizer connection is required between armatures; if the series fields are connected in the circuits of the individual machines, two must be used. For proportional division of current on all loads without rheostatic adjustment, the two sets must have similar compounding curves, and equal Ir drops in the parallel pairs of series fields of the two sets when each field is carrying the current required for proper compounding; i. e., the same current as the armature in whose circuit it is connected. Any wide departure from the proper value of currents in the series coils of the two balancer sets, will cause objectionable disproportion in division of load between the two sets with varying values of total unbalanced current. In such cases, proportionate division of current in the series coils can be secured by connecting, in series with the coils of one set, a resistance r_{ss}, whose value shall satisfy the equations:—

$$I_{ss}\, r_{ss} = I_{ss}\,(r_{ss} + r_{ss})$$

$$\text{and } I_{ss}\, r_{ss} = I_{ss}\,(r_{ss} + r_{ss})$$

PROTECTION

The design of a system of protection for three-wire circuits and of auxiliary balancing apparatus cannot follow inflexible rules, each case requiring treatment more or less on its merits. In general, two phases of the question must be kept distinct, the protection of the three-wire circuit and of the receivers connected to it, and the protection of the balancer set. Determining factors in the selection of a scheme of protection are, sensitiveness to voltage variation of the receivers connected to the system, as incandescent lights, motors, etc., size of systems and of balancing outfits used, importance of uninterrupted service, first cost, etc.

Small equipments have been frequently installed without automatic cut-outs for the balancer, knife switches only being provided for disconnecting the set from the system. Where incandescent lamp load is served, reasonable voltage balance is maintained up to the flash-over load of the balancer. Should the set be disabled by excessive short time overload, however, both receivers and balancers suffer.

A single-pole circuit breaker in the neutral lead from the balancer, operating an overload trip on the main generator or feeder circuit breaker gives more complete protection for both receivers and balancer sets. Some form of differential voltage relay may also be used which will trip the main circuit breaker when a predetermined voltage unbalance is exceeded; in this case protection for the balancer can be provided for independently by the use of suitable fuses or circuit breakers. In general, on motor load, the chief attention can be directed to the protection of the balancer.

SELECTION OF BALANCER EQUIPMENTS

The full-load rating of balancer sets is usually given in terms of unbalanced current supplied to the neutral wire at a specified line and neutral voltage. In general, for lighting circuits the balancer may be selected to provide for ten percent unbalance. The balancer capacity should, however, be determined on the basis of the half voltage load connected between the neutral and the outer wires rather than on the main generator capacity, where information is available. On large systems where the circuits can be closely balanced relatively small balancer capacity is required, while in small isolated plants the converse is usually true. Other classes of service, such as for motor drive, battery charging, etc., frequently occurs with widely varying degrees of load unbalancing; such applications require special analyses, both as to unbalanced capacity required and the most desirable type of balancing apparatus.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

790—Voltage and Power-Factor Improved by Installing Synchronous Motor-Generator—Five freight elevators are equipped with direct-current motors, totaling about 100 hp, operated with solenoid control and wound for 500 and 550 volts. They feed from a trolley circuit which varies from 500 to 650 volts, and this results in trouble with burned out motors and solenoid coils. The maintenance cost has amounted to about $850 for the past year. We also have a 1 000 k.v.a. three-phase, 440 volt system drawing, at the present time, about 300 kw with approximately 65 percent power-factor. Would it be profitable for us to install a 440 volt synchronous motor direct-connected to a 500 volt generator or a rotary converter, thus decreasing our maintenance cost on the direct-current side and increasing our power-factor on the alternating-current side. H.E.

A motor-generator set would offer a very convenient means of avoiding the serious voltage fluctuations of the direct-current source of power, and if the motor of the set is a synchronous motor, as suggested, this will serve as a means of raising the power-factor of the alternating-current load, if this synchronous motor is of sufficiently liberal design as regards field heating to allow of its being operated with over-excited fields. It will be understood that strengthening the field of a synchronous motor has the effect of causing the current which it draws from the line to lead the voltage. It is this leading power-factor, combined with the lagging power-factor of the other inductive load, which gives the resultant increased power-factor. For method of calculating the various requirements of such a proposition see article on "Power-Factor Correction" in the JOURNAL for October, 1911, p. 943. E.R.S.

791—Fluctuations Due to Starting Motors—What is the relative starting current drawn from the line in the case of a polyphase induction motor provided with suitable starter as compared with that of a single-phase motor of the same horse-power capacity of the self starting type. It is desired to use the most favorable arrangement as regards minimizing line voltage fluctuations. K.A.K.

It should be understood that, in such sizes as cover the great majority of single-phase motors, a polyphase motor could be applied without the use of a starter; say, for example, up to five horse-power. Moreover, there is no uniformity in the current drawn by a single-phase motor at starting. They may be with or without a clutch; they may be of the split phase or repulsion starting type. Everything else being equal, and assuming the use of the proper polyphase starter, the larger advantage in starting would be with the polyphase motor as against any split phase type of single-phase motor. The commutator type of single-phase motor with a starting rheostat may be started as advantageously as a wound rotor induction motor with resistance starter and would have some advantage over the polyphase type. We know of no condition where a single-phase motor of any design would not cause a momentary flicker due to starting current equal at least to that of a polyphase motor provided with starter. A.M.D.

792—Cement for Splicing Belts—Is it advisable to cement the ends of belting such as used with belt driven generators and motors instead of using lacing? Where could such cement be purchased, and at what cost? D.R.

Information is given regarding this subject in No. 670 in the December, 1911, issue. The various belt manufacturers either make or at least handle suitable material known as belt makers' cement, which will be found useful in splicing belts. The advantage of the

spliced belt, if the work is carefully done, is that the strength of the belt is not materially reduced by splicing and, what is sometimes more important, there is no sudden jerk every time the belt passes over the pulley. Commutating trouble in direct-current machines has been known to be traced to just such intermittent impulses arising from poorly laced belting. E.R.S.

793—Effect of Short-Circuit on Core Type Transformer—What is the appearance of a core type transformer after a severe short-circuit on a system of practically unlimited power. (See reference in Karapetoff's "Magnetic Circuit," p. 225, problem 20). S.C.

Unless the transformer has been designed with exceeding care, with a view to standing such service, the first short-circuit that occurs will probably mash the windings and destroy them. One of the main problems of the engineer is to work out his design, both electrically and mechanically, so that the transformer will stand up under such severe conditions. W.M.M.

794—Determination of Horse-Power for Driving Conveyors and Other Mechanical Apparatus—How may the required horse-power for driving the following conveyors be determined. There are 54 buttons attached to a three-quarter inch steel rope at intervals of three feet and these run in a steel trough which has an incline at 40 degrees, to raise material from one level to another. Each button handles about 10 lbs. of material. The ropes run through sprocket wheels at both ends of the trough and the cables and buttons return by means of rail supports. The buttons are of cast steel and the return rails wrought iron. The areas of contact between each button and the return rails is one square inch. The area of contact between each button and the steel trough is one-half square inch. There are always 24 buttons on the rail and 24 in the trough, at top and bottom. Each button complete weighs 15 lbs. With this data, can the horse-power required be figured approximately? C.J.B.

Such information is usually obtained from the builders of the apparatus, as the efficiency varies widely and they would doubtless have more useful information than could be obtained by calculation. Another method of approximating the required horse-power would be to drive the machine by means of an electric motor and determine all power required by means of suitable meters. If driven by a steam engine, the horse-power required would of course be obtained by means of indicator cards, as described in any engineering handbook. H.D.J.

795—Operation of Moving Picture Arc Lamp—(a) Would the arc lamp for a moving picture machine give satisfactory operation without a resistance connected in series in the circuit. I propose to operate such a machine from a 40 volt generator which is used in conjunction with a storage battery for lighting purposes, but have been told that the arc would be unstable without a series resistance. (b) What size and type of generator would you recommend for supplying power to an arc lamp with a sufficient additional capacity to take care of twelve 16 candle-power lamps. The motive power is a gasoline engine. E.C.

(*a*)—As neither the current rating nor voltage of the arc lamp in use are given, we cannot state whether or not it would operate from the 40 volt generator mentioned. The arc would possibly operate as a very short hissing arc, with a small amount of series resistance, but for picture operation we would recommend that sufficient series resistance be used to give steady operation of the arc. This resistance wire will serve to limit the current and keep the arc longer and steadier, or it may be that the design of the generator is such as will give poor regulation, and this characteristic drooping of voltage with increase of load may be sufficient to sustain the arc. (*b*)—We believe it bad practice to attempt to operate incandescent lamps from a small generator, the load on which is largely an arc lamp, unless the storage battery is of sufficient capacity to maintain constant voltage; voltage fluctuation due to the arc lamp operation would be apt to cause objectionable flicker in the incandescent lamps. C.E.S.

PERSONALS

Mr. J. S. Jenks, superintendent of power of the West Penn Traction & Water Power Company, with headquarters at Connellsville, Pa., has been promoted to assistant general manager with offices at Pittsburgh.

Mr. E. G. Buckwell, secretary and manager of sales of the Cleveland Twist Drill Company, Cleveland, Ohio, sailed on the Carmania on October 3 for a two months' business trip abroad.

Mr. H. L. Patterson, chief engineer of the Mahoning & Shenango Railway & Light Company, Youngstown, Ohio, has resigned to become chief engineer of the Ford City China Company, Ford City, Pa. Mr. George M. Lemon, of Youngstown, has been appointed temporary chief engineer in place of Mr. Patterson.

Mr. W. F. Fowler, formerly manager of the Pittsburgh district office of the Westinghouse Electric & Mfg. Company, and now connected with the Kuhn interests, has gone to California to accept an important executive office with the Sacramento Valley Irrigation Company.

Mr. Maxwell H. Sussman, formerly an engineering apprentice at the works of the Westinghouse Electric & Mfg Company, who has been for the past three years trouble expert and erecting engineer with the Crocker-Wheeler Company, has resigned to accept the position of chief engineer of the Cleveland (Ohio) Stove Company.

Mr. R. E. Wilson, formerly of the engineering apprenticeship course of the Westinghouse Electric & Mfg. Company and more recently with the J. G. White Company as commercial engineer at East Liverpool, Ohio, has accepted a position as new business manager for the Citizens' Light, Heat & Power Company of Johnstown, Pa.

Mr. H. W. Secor, formerly of the engineering staff of the Western Electric Company's New York factory, has resigned to become consulting engineer to The Electric Importing Company of New York City.

At the convention of the American Electric Railway Engineering Association, held in Chicago, October 7-11, Mr Martin Schreiber, engineer of maintenance of way to the Public Service Railway Company of Newark, N. J., was elected president for the ensuing year.

Mr. G. D. Piper, works accountant of the Westinghouse Electric & Mfg. Company, has been appointed director of works accounting succeeding Mr. J. McA. Duncan, recently appointed manager of the Pittsburgh district sales office.

Mr. Harold W. Brown, of the switchboard engineering department of the Westinghouse Electric & Mfg. Company, has resigned to accept a position on the instructional staff of Sibley College, Cornell University.

Mr. A. E. Jackman, formerly of the St. Louis district office of the Westinghouse Electric & Mfg. Company, has been appointed superintendent of the East St. Louis, Columbia & Waterloo Railway, with headquarters at East St. Louis, Ill.

Lucius I. Wightman, well known as a technical writer and publicity manager in connection with the manufacture of electrical and power machinery, announces his connection with a new firm to be located in the Tribune Building, New York City, to operate under the firm name of Wightman & Richards, counselors and consulting engineers in technical advertising and marketing. This represents an association of Joseph A. Richards, Mr. Wightman and Paul Morse Richards.

Industrial Engineering for October contains the article by Mr Edwin D. Dreyfus, entitled "Combined Central Heating and Electric Power Plants," which appeared in THE JOURNAL for August.

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N. E. L. A. CONVENTION AT CHICAGO IN 1913

At a meeting of the Executive Committee of the National Electric Light Association on October 11, it was decided to hold the next annual convention in Chicago, probably the first week in June, 1913.

NEW A. E R. A. OFFICERS FOR 1913

At the meeting of the American Electric Railway Association on October 10 the following officers were elected for the coming year: President, George H. Harries, president of the Arkansas Valley Railway, Light & Power Company; first vice-president, Charles N. Black, vice-president and general manager of the United Railroads of San Francisco; second vice-president, C. Loomis Allen, president of the Newport News & Old Point Comfort Railway & Electric Company; third vice-president, C. L. Henry, president of the Indianapolis & Cincinnati Traction Company; fourth vice-president, John A. Beeler, vice-president and general manager of the Denver City Tramway Company; secretary-treasurer, H. C. Donecker, Engineering Societies Building, New York City.

NEW BOOKS

"Valuation of Public Service Corporations"—Robert H. Whitten. 745 pages. Published by the Bank Laws Publishing Co., New York City. Price, $5.50.

There has been a constant increase lately in the growth and activity of commissions empowered to regulate the operation and conduct of affairs of corporations operating public utilities. The whole trend is that of establishing monopolistic institutions but at the same time keeping them under proper government and state control. Manifestly the idea of recognized monopolies and their supervision by utility commissions is fundamentally underlaid with broad political and economic principles. Although this subject has already received the attention of prominent authorities, the work Mr. Whitten has produced is signally valuable in that it not only presents an expert analysis of the essentials of public regulation but also includes a carefully prepared digest of the foremost court decision and commission rulings, with annotations that apply to rendering public service and

its details both financial and operating. Mr. Whitten is particularly qualified to prepare this volume, through his experience as librarian—statistician of the New York Public Service Commission. It should constitute an important reference volume for both operating companies and the regulatory bodies. E.D.D.

"Syllabus of Mathematics"—136 pages. Illustrated. Published by the Society for the Promotion of Engineering Education, Ithaca, N. Y. Price, 75 cents.

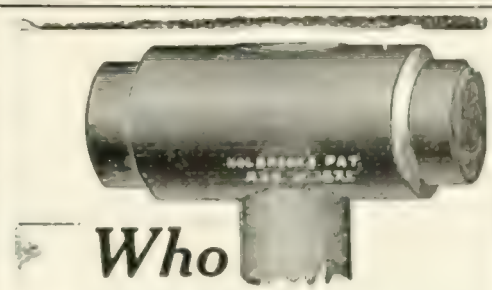
This is a symposium of those fundamental principles and methods in mathematics which should constitute the minimum mathematical requirements of the student of engineering, compiled by the Committee on the Teaching of Mathematics to Students of Engineering. The report as printed is still subject to discussion. As presented, it is divided into six parts: (1) a syllabus on elementary algebra; (2) a syllabus on plane trigonometry; (3) a syllabus on differential and integral calculus; (4) a syllabus on numerical computation and solution of equations; (5) a syllabus on geometry; (6) a syllabus of elementary dynamics. This composite work on mathematics should certainly be of interest to all students and former students of engineering. It contains demonstrations of the most approved mathematical methods and is limited to those considered the most important to the engineering student. It is in condensed form and at the same time the demonstrations are clear and explicit. The committee states that this work is not published for profit and, at the price indicated, it should certainly find a ready sale.

"A Manual of Physical Measurements"—Anthony Zeleny and Henry A. Erikson. 248 pages, 126 illustrations. Published by the McGraw-Hill Book Co., New York City. Price, $1.50.

This manual is an outline of the labratory experiments given in the one year and two year courses in general physics at the University of Minnesota. The main headings are Mechanics, Fluids, Heat, Electricity and Magnetism, Sound and Light. A number of tables of physical constants and quantities are presented in an appendix.

WANTED.

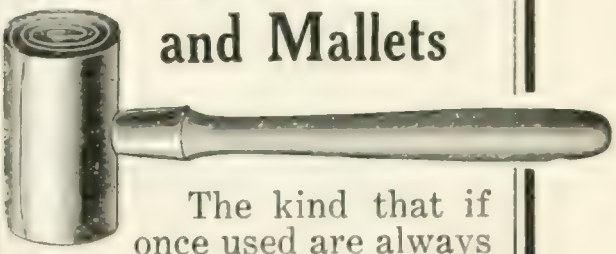
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THE
ELECTRIC JOURNAL

Vol. IX DECEMBER, 1912 No. 12

The Ethics of the Engineer

From time to time engineering societies have made an effort to formulate a code in which rules are laid down for the guidance of the engineer in his relations to his employer or his client. The desire for such a code must have been dictated by a need for it, and it is of course evident that, with the growing importance of engineering work and its increasing intimacy of relationship with great business affairs, the conduct of the engineer is by no means a matter easily dismissed as requiring no particular guidance or direction. Granting, therefore, the desirability of certain rules and directions, it must at once be inquired whether the difficulties encountered by the engineer in his conduct with employer or client are essentially different from those encountered by any other man engaged in a profession which does not belong to the trades. The rules of right conduct can be given only in their most abstract form. As a clear-minded physicist would prefer Newton's Laws of Motion in their simple and pure form, and make application therefrom to a specific problem; so should the engineer prefer the Ten Commandments and the Golden Rule in their simplicity to any derivation therefrom in the form of a code, as applied to his own problem.

Human conduct is a very complex matter, and no general rules can be followed with safety without a thorough understanding of each individual case. To take as an instance, which appears on the face very simple, the right of ownership of inventions: Let us suppose that an engineer, employed by a large corporation, which has been established in business for many years, makes an invention in connection with his work. It is reasonable to assume that such invention would not have been made if he had not been stimulated by the work done around him and, therefore, while his invention may have added to the value of the company's product, it would not have been made excepting for the company's antecedents and, hence, such invention should, by moral right, belong

to the corporation by which the engineer is employed. Let us assume, on the other hand, that an engineer should be employed by a newly formed corporation, and that this corporation should be guided and developed by him; in this event it would not appear a moral obligation on the part of the engineer thus employed to assign his inventions to his employer. Thus we have shown that, even in a case which seems so obvious, a general rule would be most misleading.

Another point, in which rather simple ethics is involved, is the question of knowledge and data which an engineer naturally gains, if employed by a corporation engaged in the manufacture of many different devices. Here again, it would seem as if a healthy moral sense would have no difficulty in deciding the question. It is one thing to learn, incidental to the pursuit of one's regular duties, and an entirely different thing to devote one's time to the acquisition of data not one's own. The carrying away of information to which the engineer has not contributed is an act of dishonesty, and it would seem hard to justify it. We are all familiar with the usual excuse given for all kinds of wrong-doing, viz., that we want a thing to which we have no right. A want does not constitute a just claim for anything that we do want.

Nor can the well-ordered conduct of business be reduced to simple rule. Business is guided primarily by a just appreciation of right and wrong, however indefinite this phrase may sound, and the infinite complexity of business conduct is reflected in the complexity of the common law which, sad to relate, has never been condensed into a compendious volume. Young engineers, like other inexperienced men, must learn the rules of life from experience; they must be wide-awake to see what goes on all around them and they should, at every step, ask themselves whether their conduct is right and well-ordered, or wrong and dishonest. With their eyes directed towards the better things of life, with their memories dwelling upon the finest types of manhood, who have been the founders of their art, they should find it no burden but an inspiration to pursue the right course of conduct in their work and, greater still, in their lives.

B. A. Behrend

Signs of the Times in Industrial Education

In the article in this issue, entitled "Means and Ends in Engineering Education," Dean Bishop has presented several interesting and important truths. Details of administration and organization may vary with different localities and institutions, but there are a few points which may be taken as signs of the times.

First—Practically all of the great engineering societies have appointed educational committees and are seriously studying this question. Its solution is no longer left entirely to the state or to the teaching profession, although those bodies too are giving it much serious attention.

Second—These engineering societies are attacking the question not purely from the point of view of increasing the efficiency of engineering training but from the standpoint of general industrial training and of social development through the increased efficiency of the rank and file of workers in the trades, such as the moulder, the pattern maker, the machinist, the electrician.

Third—Cooperative training—that is, the alternating of study of scientific principles and their practical application—in some of its numerous forms, is meeting with increasing approval.

The educational committee of the American Institute of Electrical Engineers has published its report for 1912. The following is an extract from this report, which is well worth reading in its entirety:—

"In general it may be safely stated that the continuation school in which the pupil, already regularly employed, gives a part of the working hours each week to school work, shows distinct and positive signs of being best suited to the conditions facing the great majority of young men.

"These schools, whether maintained at public expense or by industrial corporations, should aim to develop the mental judgment and physical skill required for promoting the industries in the localities in which they are situated. This means very close correlation between the school work and the shop work in which the youth is engaged."

The educational committee of the American Federation of Labor, in its report for 1912 has the following to say:—

"The public schools should teach the theory of the trade, while the actual practice and processes should be taught in the shop. * * * We believe that the education of workers in trade or industry is a public necessity, and that it should not be a private but a public function, conducted by the public and the expense involved at public cost."

Senate Bill No. 3 now before Congress provides that the Fed-

eral Government, "coöperate with the States in encouraging instruction in agriculture, the trades and industries, and home economics in secondary schools; in maintaining instruction in these vocational subjects in state normal schools; in maintaining extension departments in state colleges of agriculture and the mechanic arts; and to appropriate money and regulate its expenditure."

This is generally known as the Page-Wilson Bill and the National Society for the Promotion of Industrial Education is conducting an active campaign in support of this Bill. Its members are being urged to get into communication with congressmen from their respective districts. This Bill is now in the hands of the House Committee on Agriculture of which Hon. John Lamb of Virginia, is chairman.

Notwithstanding the importance of all these things, the keynote of industrial education for social efficiency is not the study of school curriculums, equipment, teachers, or even legislaton, but the study of young boys and girls, so that each may be placed in that line of work for which by nature each is best suited. It may sound well to offer to each American youth the opportunity to do anything that may strike his fancy, but society cannot afford the thousands of misfits which this very method has produced. We applaud success and ignore failure, even if one succeeds where a thousand fail. The educational work of the future will be directed towards raising the general average, rather than the standard of a comparatively few individuals.

C. R. Dooley

Nine Years of the Journal

The present issue completes the ninth volume of the Journal. Starting in 1904 in a comparatively simple style as a magazine for the young engineer, there has been a steady increase in the scope and number of reading pages, and in the interest evidenced by the engineering public. The original policy of discussing engineering matters in simple, concise language has been consistently followed. In preparing technical contributions for publication the aim has been to see that each step is clear, to give reasons and explanations wherever they will tend towards a better understanding of the text, while at the same time making the articles as direct and brief as possible.

This method of presentation combined with unusual facilities for securing timely contributions from authentic sources on the most recent developments in the electrical art has had much to do with

the rather remarkable success of the JOURNAL. The great majority of JOURNAL contributors are men who are actively employed in important engineering work and who do not ordinarily write for publication, but who are willing to give of their experience for the benefit of JOURNAL readers. A considerable number of these contributors, in their every-day work, are engaged in developing improved types of apparatus and methods of utilizing power. The JOURNAL, on account of its location n a great engineering center, is in a position to keep its readers in intimate touch with those who are best informed regarding current engineering practice. The means of generating and applying electricity are being improved and added to so rapidly that, in order to keep abreast of modern progress, one must make use of the best sources of information available. Readers of the JOURNAL all over the world have shown marked appreciation of the efforts made to give them accurate engineering discussions which are not only interesting but worth keeping for future reference.

With the closing of the present volume some 7 600 pages have been published. During the present year 154 500 copies were issued, an average of 12 875 copies per month. Over 9 600 bound volumes have been sold, representing over 115 000 copies which are being kept for reference in permanent form. In the Question Box Department some 815 questions and answers have been published and many more inquiries have received personal replies.

While these figures are interesting in retrospect, the editors of the JOURNAL are more interested in determining plans for the future. They can judge in a general way from the subscription records that the JOURNAL is giving satisfaction to its subscribers, from the fact that eighty-five percent of them are renewing each year. But such facts are general and give no indication of the particular features which are considered most important. What is especially desired is a considerable number of direct requests for specific types of articles, for information along certain lines, etc. The editors of the JOURNAL are anxious to assist subscribers who will indicate those problems which seem to need solution most urgently. The reading pages of the JOURNAL are largely devoted to material of an educational nature; its students, however, form an immense class whose training has been of various kinds. To serve the interests of all most effectively is the problem of the JOURNAL editorial staff. The coöperation of subscribers generally, by indicating their personal needs for definite discussions, will prove mutually helpful.

STABILITY OF THE ELECTRIC ARC

G. W. ROOSA

AN electric arc is a gaseous medium, conducting current and depending upon that current for its generation. There are gaseous media which will conduct current, but which are not electric arcs except in that portion of the gas in which current is flowing. For instance, an acetylene gas flame can be made to conduct current, the arc and a portion of the gas flame becoming co-incidental and co-axial. However, the arc proper is the gaseous medium generated from the electrode materials by the current.

All gases regardless of the means of generation and regardless of their constituency exhibit certain physical properties, such as diffusion, expansion, etc. A gas may be an element, a compound or a mixture of elements and compounds and it may carry in suspension minute solid particles that may be elements, compounds or mixtures. Definite chemical and electrical phenomena and properties are evidenced by all gases, depending upon their chemical constituents.

With the electric arc, however, we find electrical phenomena which are more or less independent of its chemical constituency, its physical state and of the gases in which it exists. These phenomena distinguish it as an electric arc and are accounted for in several theories which are upheld by the careful researches of Steinmetz, Blondel, Mrs. Ayrton, Child and other scientists. It is not the purpose of this discussion to comment upon these theories, but rather to point out a property of the electric arc that is worthy of note by all of its users, whether they employ it in the electric furnace, the arc lamp or the nitrogen generator. This property may be called stability because the arc cannot exist without it. It is directly related to the sustaining power and rigidity of the arc, the first factor lending continuity of existence and the second, shape and position.

Due to physical and chemical properties common to all gases, and to certain electrical properties the gaseous medium of the electric arc is constantly dissipated by convection, diffusion, expansion, combustion, etc. Hence it must be replenished in some manner. This takes place at both the anode and cathode, the latter without doubt generating by far the larger amount of the gaseous conductor. It can be shown by a variety of experiments that the gases generated by the cathode perform a function more important than those by the anode. The absolute necessity of the

continuity of the cathode spot and its vapor blast in the mercury arc rectifier*, and the case of transfer of the anode spot from one anode to another, indicate that the gases produced at the anode spot play a small part in the generation of the gaseous conductor and the maintenance of the current flow, as compared with those produced at the cathode spot.

NORMAL ARC

If it be assumed that an electric arc in the vertical position as in Fig. 1, is burning in an atmosphere devoid of other air currents than those of convection resulting from the heat of the arc; devoid of pressure variations, and variations in local magnetic fields; that it is burning between two horizontal parallel electrode surfaces with the blast issuing from the lower electrode, and not issuing from a molten or heterogeneous portion of the electrode; if the arc stream be assumed devoid of weight and therefore devoid of inertia; and if expansion, diffusion and radiation take place everywhere at a constant rate at right angles to the line of current flow, then there exists no external or internal force to vary the cathode blast from this direction. The power of continued existence in a given position and to maintain a constant shape, under these conditions with a constant voltage supply is called stability.

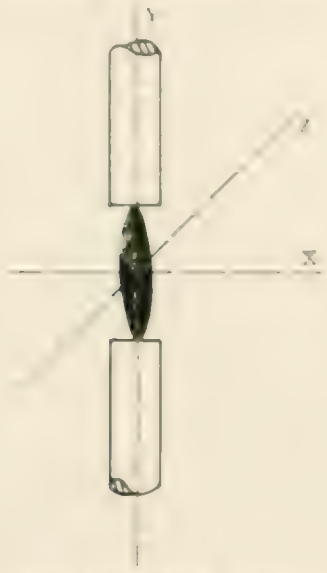


FIG. 1 — NORMAL ARC

SUSTAINING POWER

As the continuity of existence is dependent to a great extent upon the cathode blast, the sustaining component of stability may be represented by the energy consumed in the generation of the gaseous medium. To simplify matters assume that Fig. 1 represents the normal arc. Any force external or internal overcoming its sustaining power must act in the direction of the Y-ordinate and therefore may be represented by F_y. The value of F_y is the reduction in e.m.f. necessary to reduce the current to such a degree that the energy consumed in the production of the gaseous conductor falls below that required to generate a sufficient amount of these gases.

*See "The Theory of the Operation of Mercury Rectifiers," by Mr. R. P. Jackson, in the JOURNAL for June, 1912, p. 565.

A fair example of a normal arc is shown in Fig. 2. This illustration is a sketch from a four ampere, 66 volt metallic flame arc lamp.



FIG. 2—SKETCH OF NORMAL 4 AMPERE, 66 VOLT METALLIC FLAME ARC

RIGIDITY

The rigidity of the arc is its power to overcome forces tending to move or bend it from the normal position. Its value is independent of the energy consumed at the cathode blast. Referring again to Fig. 1, it may be seen that any force external or internal opposing rigidity must act at right angles to the Y-ordinate. It may, therefore, be represented by F_{xz}. The value of F_{xz} necessary to make an appreciable alteration in shape or position of the arc is very small. It is not definitely measurable as in the case of F_y.

ABNORMAL ARC

Assume an arc of any other shape such as *a, b, c, d* or *e*, Fig. 3, to be an abnormal arc. A normal arc becomes abnormal as soon as affected by the force F_{xz}. The force now necessary to overcome the sustaining power is not in the Y-direction but at an angle to it. It is always in a direction coaxial with the path of the current except when, as in *d* and *e*, Fig. 3, the arc lengthens so far that the potential drop from electrode to electrode or between two points of the arc stream is equal to or greater than the e.m.f. required to jump that distance. Then the

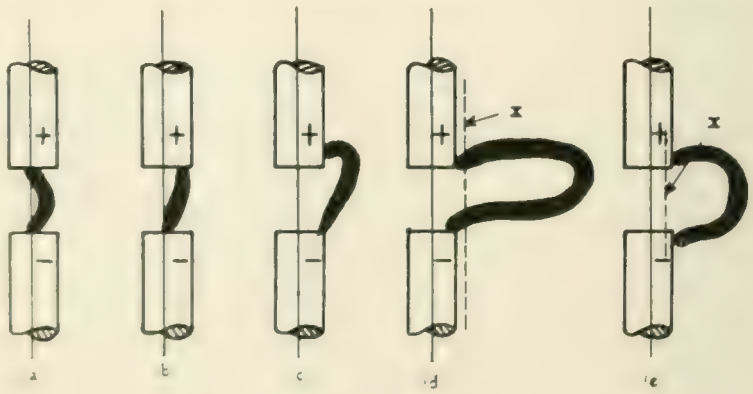


FIG. 3—ABNORMAL ARC

a—Arc stream displaced. *b*—Anode displaced. *c*—Entire arc displaced. *d* and *e*—Arc near reformation.

direction of the force is such as to establish a new arc, or path of current flow, taking the place of the original one at such positions as illustrated by the dotted lines x in d and e of Fig. 3. Then the force necessary to overcome the sustaining power is in the direction of the dotted line.

Also any force, external or internal, affecting rigidity in an abnormal arc must act at right angles to the direction of the current path. Thus it may be acting in a combination of X, Y or Z directions depending upon the point of application.

INHERENT PROPERTIES REDUCING STABILITY.

Because it is a gaseous conductor the electric arc possesses qualities (some of them not found in liquid conductors and still more not found in solid conductors) that detract from stability. They are outlined below in their apparent order of influence.

Gaseous State—Unlike solid and liquid conductors the shape, size and position of the gaseous medium is constantly varying.

Ratio of Length to Cross-Section—Ratio of length to cross-section is in general the ratio of the arc voltage to the current. An arc of high ratio is lacking in stability.

Condition of Cathode Spot—A liquid condition of the cathode spot gives evidence of easy movement of the arc. Thus the mercury electrode of the mercury rectifier shows rapid motion of the cathode spot. Molten iron on a cathode of iron exhibits to a less degree the same effect.

Direction and Inertia of Cathode Blast—The main force of the cathode blast may not be directly toward the anode spot, thus causing an abnormal arc as *c*, Fig. 3.

Flexibility—Due to this property the arc can be distorted into almost any shape.

Weight—A gaseous medium of light weight is most easily affected.

Undoubtedly radiation, expansion and diffusion play a part in the maintenance, shape and position of the arc, but the effects produced are of a minute order.

To say that the sustaining power would be increased or decreased directly by any of the inherent properties mentioned above would be misleading, but it is true that rigidity and sustaining power are inter-connected, due to these inherent properties, and variations in ratio of length to cross-section and the condition of the cathode spot are directly connected with the maintenance of the arc.

The ratio of the voltage of the arc to that of the steadying resistance or reactance on constant potential circuits, or the steadying effect of the constant current regulating transformer on constant current circuits will affect materially the sustaining component of stability. In other words arcs cannot be operated on constant potential if the ballast effect is too low. As soon as the current decreases to a certain value the watts consumed at the cathode do not generate proper quantities of the gaseous medium. In a constant current circuit if we eliminate the steadying effect of the regulating transformer it becomes a constant potential circuit and the above conditions exist.

Practically everyone of the inherent properties outlined rob the arc of rigidity. Due to their combined existence the arc is most readily moved near its centre, less affected at the anode end and least affected near the cathode. There are also some external variables controlling and limiting the effects of a given force F_{xz} upon the arc or upon different portions of the arc. For instance, the atmospheric pressure will determine the density of the arc and thus its shape and position. Impurity and heterogeneity of electrodes cause variations in the direction of cathode blast. This is practically similar to an external force F_{xz} applied at the cathode spot.



FIG. 4—ELECTRIC ARC IN THE VICINITY OF A UNIFORM FIELD

RESULTS PRODUCED BY VARIOUS FORCES ACTING UPON THE ARC

The forces resulting from air currents, magnetic fields, movements and presence of solid obstructions, etc., affect the rigidity component first, and finally the sustaining component. The result is a change of the arc from normal to abnormal shape by deflection first, followed by an actual change of position and ultimately an irregular elongation terminating often in the rupture of the arc. The forces due to variations in the inductance or resistance of the external or internal circuit affect the sustaining component only.

Air Currents—The effects of air currents upon the arc stream might be detailed into an elaborate discussion, but one or two of the most important are worthy of note at this time. A draft of air producing a force at right angles to the line of current flow will move the arc to one side and, if of sufficient strength, will lengthen it as in *a*, *b*, *c*, *d* and *e*, Fig. 3 to its ultimate strength. The ultimate

strength of an arc is the minimum value of stability and occurs when the energy available for the production of the gaseous conductor falls below that required to supply a sufficient quantity of gaseous medium for proper conduction of current. This quantity varies under many conditions of temperature, pressure, etc.

An air current moving co-axially to the electric current flow, whether positive or negative in direction relative to the direction of cathode blast, changes the sustaining component of stability by variations in the percentage of vapor entering into the arc stream as useful conducting vapor. A peculiarity of this nature in commercial application occurs in the metallic flame arc lamp, Fig. 2, when a draft of air co-axial with the arc and in the direction of the cathode blast tends to eliminate the effects of forces acting at right angles

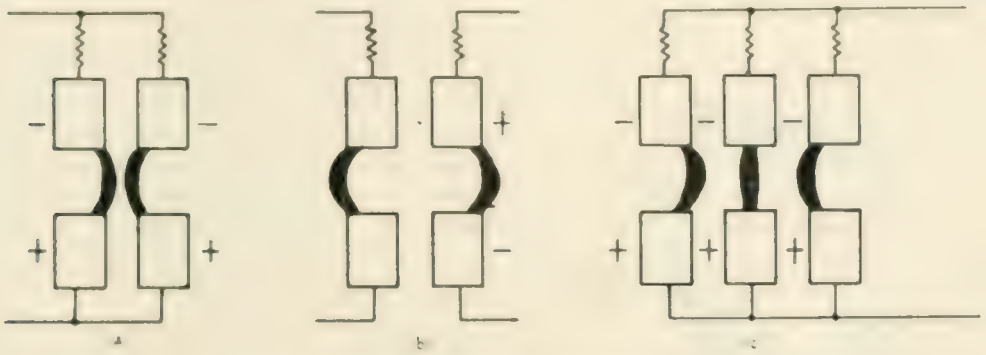


FIG. 5—INTERACTION OF PARALLEL ARCS

a—Two arcs attracting one another.
b—Two arcs repelling one another.
c—Two arcs neutralizing the field around a third arc between them.

to the current flow. This is evidenced by a steadier arc than when the co-axial movement of air is absent.

A sudden change in the direction of the cathode blast is often caused by air movements which extinguish the arc by the reduction of the sustaining power. In this connection it is interesting to note that the arc may never reach its ultimate strength under the force of a constant and steady draft but the sudden termination or restarting of this draft, whether in the *X*, *Y* or *Z* direction, will often extinguish the arc. This is no doubt due to the sudden change in direction of a part of the arc stream, at which time the cross-section, the current, the watts at the cathode and thus the sustaining power are reduced to the minimum value. In small energy arcs, such as in the arc lamps consuming from 300 to 500 watts, draft conditions in the vicinity of the arc should be carefully considered.

Magnetic Fields—To the extent of complete elimination, mag-

netic fields in the vicinity of an electric arc are unavoidable and inasmuch as the slightest magnetic field produces perceptible changes in the shape and position of the arc stream, undesirable in arc lamps, but desirable in magnetic blow-out apparatus, their laws must be understood and the strength of the fields controlled.

The laws of direction and magnitude of a force produced by the presence of a current-carrying gaseous conductor in a magnetic field, are the same as those in a current-carrying metallic conductor. A given current in the conductor of one centimeter length whether a solid, liquid or gas, and in a magnetic field of intensity H will exert a force of $I\ H\ L$ dynes at right angles to the current flow. Thus:—

$$F = I\,H\,L$$

When F = dynes, L = centimeters of conductor in the presence of magnetic field of H intensity and I = the value of the current.

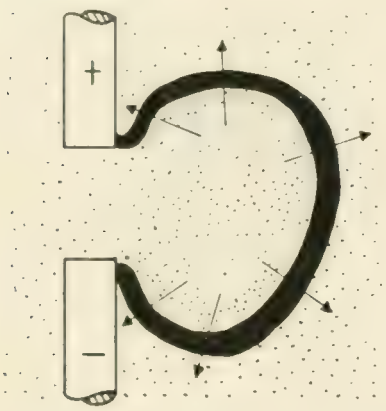


FIG. 6—ELONGATION OF AN ELECTRIC ARC SHOWING THE FORCES ACTING IN VARIOUS DIRECTIONS JUST BEFORE ULTIMATE STRENGTH IS REACHED

The result of this in the solid conductor is a tendency to displace the entire conductor but in the case of the arc those portions, which are less rigid than others, are displaced more. This results in many peculiar distortions of the arc.

Suppose, for instance in Fig. 4, that current is flowing from the positive to the negative electrode and that a magnetic field of uniform density is present at right angles to the surface of the page. In the illustration the flux is considered as positive in the direction away from the reader. The separate fields of the arc and of the vicinity do not exist alone but the resultant flux to the right of the arc is decreased and to the left increased. This is an old and familiar illustration, hence explanation is unnecessary.

Some interesting experiments, as illustrated in Fig. 5 *a*, *b* and *c*, show the effect of neighboring arcs, each one being in the vicinity of the magnetic field from the other. In *a* two arcs of the same polarity tend to coincide, in *b* two arcs of opposite polarity repel each other and in *c* a stray field is neutralized by another stray field. If an alternating field is imposed upon a direct current arc or vice versa, the result is a synchronous movement of the arc to the right and left appearing to the observer as two arcs.

The arc in Fig. 6 is on a direct current, 600 volt circuit in series with considerable inductance and resistance, thus increasing the sustaining characteristics. The forces exerted due to a uniform field similar to that assumed in Fig. 4 act always at right angles to the current direction as shown by arrows at various points. As the arc elongates it changes from a straight to an arched stream and even to a circular stream reaching the ultimate strength at about the shape shown in Fig. 6. It is evident that a large variety of shapes is possible. Many pretty experimental arcs can be produced by the imposition of magnetic fields upon flame arcs.

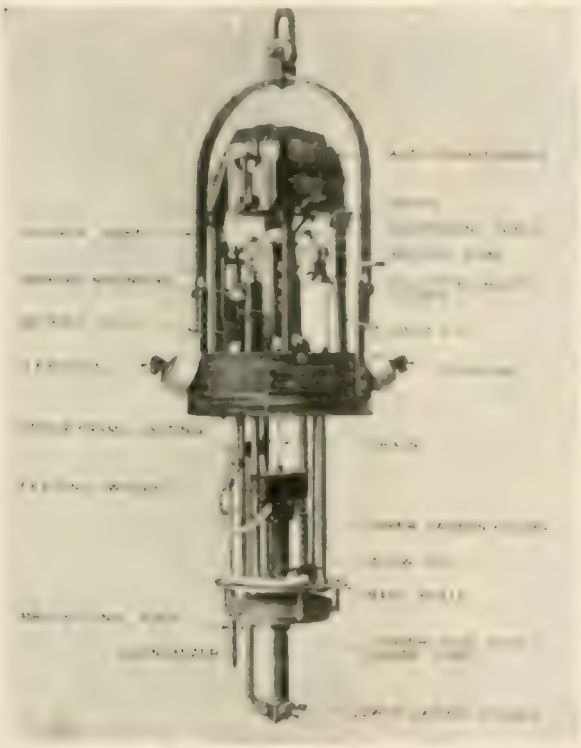


FIG. 7—LONG BURNING ALTERNATING CURRENT FLAME CARBON ARC LAMP

Designing engineers utilize these laws in the prevention of side blowing of the arc in arc lamps, in the sudden extinction of the high energy arc of the magnetic blow-out circuit breaker and in the repeating arc of the nitrogen generator by reformation as in Fig. 3, *d* and *e*. Fig. 7 shows a modern flame carbon arc lamp, employing a magnetic blow coil to neutralize the flux from the current in the side rod.

Solid Obstructions — The intervention of a solid obstacle, such as a small copper rod, will cause the arc to bend to one side and conform to the shape of rod. However, unlike a gas flame it will not surround the rod but must pass only on one side. The movement of a copper bar across the arc exerts a force pushing the arc to one side changing its shape and position and ultimately causing it to rupture. If, however, the obstruction is small in cross-section and cuts the arc near the anode end of the arc stream, rupture does not always occur.

A photograph of a 15 ampere, 218 volt iron arc, distorted by the presence of an obstruction, is shown in Fig. 8. The straight line distance between electrodes is 1⅛ inches but the arc is bent out considerable, passing around the one inch copper pipe placed directly between the electrodes.

Cathodic Recoil—Arcs issuing from a molten cathode appear to cause a depression in the molten mass up the sides of which the cathode spot is constantly climbing. This action results in a constant traveling of the arc. It may be considered as the result of a force F_x applied to the arc approximately at the cathode. Rupture seldom results, for the sustaining power is little affected by it.



FIG. 8—IRON ARC OF 15 AMPERES AND 218 VOLTS SHOWING DISTORTION DUE TO THE PRESENCE OF A ONE-INCH COPPER PIPE

Counter-e.m.f. or Variations in Circuit Inductance or Resistance—The only force directly opposing the sustaining component of stability is a force accompanying an increase in e.m.f. supplied. If, due to elongation, the internal resistance or inductance of an electric arc increases, an additional internal e.m.f. is required and when, as in a constant potential circuit no provision is made to supply additional e.m.f. the sustaining component of stability is reduced, the extinction of the arc follows providing its ultimate strength is reached. Should the external circuit by some means exhibit increase in resistance or inductance, the arc voltage would be reduced. This, then, is also a force acting directly on the sustaining power of the arc. However, the presence of constant values of resistance and reactance produces a very steady arc by storing energy and supplying it to the arc when decreases of supply voltage occur.

MEANS AND ENDS OF ENGINEERING EDUCATION*

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THE fundamental object of engineering education as of all higher education is the development of character and the preparation of the young for citizenship. Instruction, which is but a part of education, has for its object the development of the intellect and the transmission of knowledge. However, instruction is not the principal part of education; for character is more essential than either knowledge or intellect. In college we do more than learn the lessons given us; we live in an intellectual and moral atmosphere, acquire habits of thought and behavior. "To imagine that youths who have passed through college and universities, and have acquired a certain knowledge of languages and sciences, but have not formed strongly marked characters, should forge to the front in the world and become leaders, is to cherish a delusion."

The methods to be employed for the development of character do not differ materially in the engineering school from those employed in the college of liberal arts. It is not, therefore, my purpose in this paper to discuss these methods which should be common to all educational institutions, but rather to deal with the best conditions and methods for imparting to students the knowledge which is most important for the engineering profession, remembering always that everything tends to form character and that this is fundamental.

From the undergraduate department of a school of engineering we may expect men who will fall in either one or the other of two classes, namely, the designing engineer or the productive engineer. In other words, the school must produce not only the man who has a knowledge and knows how to use it, of physics, mathematics, properties of materials, etc., but also the man who possesses this knowledge combined with an understanding of human nature, obtained by actual contact with man, a knowledge of the economic importance of the various factors which enter into the output of any concern, together with an appreciation of the fact that expediency enters into all engineering problems.

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*Abstracted from a paper read before the Pittsburgh Section of the American Institute of Electrical Engineers, November 12, 1912

SELECTION OF THE FACULTY

The first and, perhaps, determining factor in any school is its faculty, upon the selection of which depends the character which is to be given to the teaching of the school. Mr. Gano Dunn, junior past president of the American Institute of Electrical Engineers, in his presidential address, indicated the main object of engineering education, as follows: "The profession of electrical engineering not only deals with single-phase motors, storage batteries, high-tension transmissions, turbo-generators, coronas, carbon transmitters and commutation, *as an occupation,* but it also is a *way of thinking,* and as such is not an occupation, but the latest and most highly developed scientific method of solving all kinds of practical problems of matter and force, for the benefit of the human race."

If we are to consider engineering as a way of thinking, it is important that members of the faculty be men who represent this idea; men who consider engineering as a way of thinking rather than an occupation; in other words, men who apply this method of thinking to many problems outside of their occupation.

The members of the faculty exert an immense influence upon the lives of the young men with whom they come in contact. This influence is so subtle, many times, as to be almost impossible of discovery. It often extends to the assumption of mannerisms of the instructor as well as the reproduction of his general habits of thought. It is, therefore, important that the student should come in contact with the very best minds; men who have the highest ideals of the engineering profession.

In general the policy employed in the selection of a faculty has been to select an individual graduate, make him an assistant, later an instructor, and finally a professor. His entire training may be, and often is, confined to his undergraduate course, and what he has learned from the students he has taught. This type of man becomes convinced that he is an authority mainly from the fact that he has been dealing with inferior minds who naturally look to him as a leader.

That this type of man did not make the best teacher was recognized a number of years ago when an attempt was made in certain schools to remedy this evil by having the instructors spend a part of their time in practical engineering work. This is, however, only a partial solution. It would seem advisable to reverse the order and have on the faculty a few men who devote most of their time to the practice of their profession, but who will devote to the school suffi-

cient time and energy to impress upon it and the students with whom they come in contact the best ideals of the engineering profession. A faculty, if properly adjusted in numbers and ability between those who devote the major part of their lives to education and those who devote most of their time to the practice of their profession, would provide, I believe, an ideal faculty. When these practicing engineers act as heads of departments it is necessary to have under their direction a competent younger man who is the operating head of the department.

SELECTION OF STUDENTS

The manufacturer of high grade machinery, instruments, etc., must, if he is to have a first class product, begin by a proper selection of the material which is to enter into his finished product. This is especially true of engineering schools which desire to produce high grade men. Two main methods are employed for selecting freshmen for entrance to college, examination and certificate. The first method is based upon the old English style of education, which is to judge a man's knowledge by his ability to pass an examination. This method is growing obsolete in this country. The second method, that of admission by certificate, is a far superior one if properly administered.

A school of engineering at a university possesses inherent advantages over the separate engineering school in the selection of its upper classmen from the freshmen. When a freshman in engineering displays an utter lack of appreciation of those subjects which go to make an engineer, he can be advised to transfer to some other school or department which seems more nearly adapted to his ability. Many students enter the engineering courses without any appreciation of the hard work necessary to complete the course or the duties of an engineer. Each student should be given every possible opportunity between the time he enters and the time at which he must select his particular course to become acquainted with the profession which he proposes to follow.

This is much more important in engineering than in law or medicine, because as a boy he does not in general have the same opportunity to come in contact with members of the engineering profession that he does with others.

Lectures by prominent engineers covering many phases of engineering work together with visits of inspection to many kinds of engineering plants should constitute a part of the required work of

the first two years. In addition frequent conferences with the members of the teaching staff should be held.

ENVIRONMENT

The effect of environment or location of the school of engineering upon its students has received very little consideration until recently. However, it is recognized that there are two classes of colleges: the country and the city college. In the former the whole life of the student is bound up in the small circle which revolves within the college town. This is the old type of classical college in this country and has many things to commend it.

In the other college, the life within the school is only incidental to the greater movements which are taking place. The student is in constant contact with the current events in the business world, with the development and solution of various social and economic problems. In engineering he is in constant contact with the best methods of manufacture in various lines. He listens to lectures by the engineers, becomes a junior member of an engineering society and by means of visits of inspection, coöperative work, etc., is alive to changes which his profession is undergoing and enters the spirit of it long before graduation.

Education has been defined as the adaptation of the individual to his environment. One of the chief criticisms against the schools of engineering has been that the young graduate did not readily adapt himself to his surroundings. This has been well founded and its cause probably arises from the fact that the student during his four years at school has lived in an artificial atmosphere. It is evident then that the engineering school must be located in an engineering center where the student engineer can observe the generation and transmission of large quantities of power, study the properties of material while in the process of manufacture, etc. Such facilities are afforded only at the large industrial centers and nowhere are they so well exemplified as at Pittsburgh.

COÖPERATIVE WORK.

A logical outcome of the location of a school of engineering in an industrial environment is some form of coöperative work whereby the student can make the most of his opportunities. This work originated with Dean Schneider of the University of Cincinnati and a modification of it was adopted by the University of Pittsburgh some three years ago.

The plan in brief is this: During the freshman year the student

remains in school the entire time. During the sophomore and junior years he spends half the time in school and half in practical work, interchanging every three months. During the senior year he spends his entire time at the University. By this means the faculty send out into practical work only those men with whom it is acquainted, and consequently the grade of men given to the industrial establishments is fairly good.

It would seem that the fundamental principle of the cooperative work lies in the fact that a freshman is intensely interested in those things which do not materially interest a senior or a graduate student. The whole operation of a manufacturing concern or the construction of any great engineering work appeals to the imagination of the freshman who is engaged in it, in a way that it does not to the graduate. He is anxious to do his work well in order to demonstrate to the working man and his colleagues that he is the equal, and possibly the superior, of any of them.

The acquaintances made by the student among the engineers and others employed by the concern is certainly a marked advantage to the student. The engineers and others under whom the students work feel a certain responsibility toward these men, in that they are assisting in their training. The student in return feels that he represents the University while in coöperative work and that the reputation of the University depends upon his conduct. The coöperative students are tremendously interested in their work and consequently can do a larger amount of work in the same time than it would be possible to do with the average student body.

The close personal contact with the faculty which it is necessary to maintain; the constant intercourse with superior men in engineering work tends always to develop the student into a dignified, self-reliant man. Students enter upon the first period of coöperative work at the end of the freshman year as boys; after three months they return to the university with the characteristics of men.

men.

The preceding paragraphs give in outline some of the means which can be employed to develop from the raw material which comes to us from the high school those characteristics which will cause the young engineer to look upon the profession not only as an occupation, but as a way of thinking; those methods which seem to be well adapted to develop the initiative faculty and increase his efficiency as an engineering student.

TUNGSTEN LIGHTING IN MODERN INDUSTRIAL ESTABLISHMENTS

ALEX. J. AIRSTON

MANY articles have appeared recently in technical journals on the subject of tungsten lighting in factories and offices. It is, therefore, the purpose of the present article not so much to add further information, as to give in practical form the fundamental requirements of lighting installations, based both on theory and experience. A few simple rules are presented which will enable the reader to design easily, an efficient and adequate system of tungsten lighting for almost any location in a modern industrial establishment.

The design for illuminating a location is dependent upon:—

1—The height and type of ceiling or roof.
2—The class of work carried on in the location.
3—The character of the surroundings.
4—The area and shape of the location.
5—The illuminating system to be replaced (if any).
6—The cost of the installation.

The rules for procedure must depend on these factors, although the order need not be followed.

1—The necessity of attention to the height and type of ceiling is self-evident upon reference to Table 1, in which a list of

TABLE I

Mounting Height, ft.	Size of Lamp Watts	Mounting Height, ft.	Size of Lamp Watts
7 to 10	40		
8 to 12	60	7 to 12	60
10 to 14	80		
12 to 16	100	11 to 16	100
14 to 20	150		
17 to 27	250	16 to 28	250
25 to 35	400		
30 to 40	500	28 to 40	500

mounting heights for different types of tungsten lamps is given. In a manufacturing area, the direct system is almost invariably employed and the lamps mounted within a foot or two of the ceiling or on stringer boards which span the space between the lowest members of roof trusses at intervals where rows of lamps are deemed necessary. The advisability of high mounting will be appreciated from the fact that the lamps are then out of the way of cranes, are less liable to be broken, the glare is reduced to a minimum and in the case of a light ceiling there is more reflection and better diffusion of light. However, the lamps should be lowered in locations

where there is horizontal overhead belting, to the level of the bottom of the belting, otherwise the light is ineffective, a considerable portion being cut off. Occasionally it may be necessary, for the same reason, to install two or three 100 watt units in a given area where the conditions would otherwise warrant a single 250 watt unit.

In office lighting the direct, indirect, or semi-indirect system may be used. The lower intensity lamps such as the 60 watt unit, give more satisfactory results than those of higher candle-power. This is due to the fact that the glare, and inconvenience from shadows is reduced to a minimum. Ordinarily the lamps should be mounted near the ceiling; however, whatever the height of the ceil-



FIG. 1—SEMI-INDIRECT DRAFTING ROOM LIGHTING

The illumination secured in rooms equipped as shown above is well diffused and is free from sharp and objectionable shadows.

ing, the mounting heights should be approximately the same for any one size of lamp, since it is advisable to standardize as far as practicable the sizes of lamps and reflectors, thus securing from one size the same foot-candle intensity per lamp on the working plane.

In the case of drafting rooms a semi-indirect system with reflection from light ceiling and walls, or diffusers, is effective, the lamps being mounted within a foot or so of the ceiling up to 16 feet ceiling height. Clusters of four 60 watt lamps on a fixture with opal glass reflectors throwing the light upwards, the clusters placed eight feet apart from center to center as shown in Fig. 1, have been found to give excellent results at a mounting height of 14 feet with a ceiling 16 feet high.

2—The class of work carried on in the location under consideration determines the "watts per square foot" to be used. In Table II, the "foot candles" as well as the watts per square foot are shown. Where the kind of light made use of is the same throughout, and the mounting heights of the units, dependent upon the size of the lamps, vary within such limits as are set forth in Table I, designing by means of the "watts per square foot" method is preferable to the lumens method (not described here), both for comparisons of installations and actual calculations. It is assumed from the study of different installations that one foot-candle intensity on the working plane is given by one-half watt per square foot. This figure is only approximate but is a fair index of what may be anticipated if the

TABLE II

Class of Work	Foot candles	Watts per sq. ft.
Office—General	3	1.4
—Close work	3.5	1.7
—Curve work	5	2.5
—Drafting	7	3.5
Vaults	1.5	0.75
Corridors	1	0.5
Power House	2	1
Average Manufacturing Work—Machine and Bench	3	1.5
Particular Machine or Bench work	4	2
Storerooms	0.5 to 3	0.3 to 1.5
Inspection	5	2.5
Woodwork	4	2
Toolrooms	3	1.5

rules given are followed out. The size of the lamp is decided upon from Table I, and the watts per square foot from Table II. Then the ratio, wattage of lamps divided by watts per square foot, gives the area of the square of which the lamp is the center. Taking the square root of this, the length of the side of the square or the "ideal spacing distance" between the lamps is obtained, for if the lamps are placed at the corners of squares throughout the location the best distribution of light is secured. Putting W = wattage of lamp, A = area of square, w = watts per square foot and d = ideal spacing distance, than $d = \sqrt{A} = \sqrt{\frac{W}{w}}$

3—The third of the above six points guides the designer in making his calculations, so that in choosing from the Table II, the "watts per square foot," which is the basis of the design, a variation up to 15 per cent above or below the given figure may be allowed depending upon whether the surroundings are dark or light.

4—The area and shape of the location to be lighted has a very decided effect upon the layout of the installation, as do also the positions of any obstacles that are liable to interfere with the hanging or placing of the lamps or the shedding of their rays on the working plane. A row of lamps should be hung in fairly close proximity to walls particularly in office lighting which demands a row within 2 ft., 9 m. of side walls, but in manufacturing spaces each case should be taken on its own requirements. Again lamps near windows

TABLE III

Size of Lamp W	Mounting Height	Watts per sq. foot w	Ideal Spacing Distance $\sqrt{W/w}$	Minimum Spacing Distance	Maximum Spacing Distance
Watts	Feet	Watts	Feet	Feet	Feet
40	7 to 10	1	9 6	8 0	10 0
		1.5	5 2	4 6	6 0
		2.5	4 0	3 9	4 3
60	8 to 12	1	11 0	9 6	12 9
		1.5	6 4	5 6	7 3
		2.5	4 11	4 6	5 6
80	10 to 14	1	12 7	10 6	15 0
		1.5	7 4	6 6	8 3
		2.5	5 8	5 0	6 6
100	12 to 16	1	14 5	12 6	16 6
		1.5	8 2	7 0	9 6
		2.5	6 4	5 8	7 0
150	14 to 20	1	17 4	15 0	20 0
		1.5	10 0	9 0	11 0
		2.5	7 0	7 0	8 6
250	17 to 27	1	22 5	20 0	25 0
		1.5	13 11	11 9	14 3
		2.5	10 0	9 0	11 0
400	25 to 35	1	28 2	25 0	31 6
		1.5	16 4	15 0	17 6
		2.5	12 7	11 6	13 6
500	30 to 40	1	31 7	28 0	35 6
		1.5	18 6	16 6	20 6
		2.5	14 2	12 6	15 6

NOTE.—The difference between spacing distances in the two directions should never exceed 25 percent of the ideal spacing distance.

should be wired to one switch for economy, as should also any lamps extensively used at different times from others. Also before placing the lamps preliminary sketches should be made and different spacing distances tried out until a satisfactory design is completed which evades all obstacles and approaches as near as possible to the ideal spacing distance. Table III shows the ideal, maximum and minimum distances for the different types of lamps.

5—In many cases a system of illumination is already installed and it is required to replace this with a new tungsten installation

The switching, wiring and position of the old outlets should be carefully considered with a view to using part of the old system in order to keep down the cost of the new.

6—The cost of the installation is an important factor affecting the design and from a rough calculation based on the total area of the room multiplied by the watts per square foot and divided by the wattage of the lamp an approximate figure of the number of lamps required is obtained. Putting $n =$ number of lamps then, $n = \frac{Aw}{W}$. The cost per lamp installed complete is determined from experience and hence if the price of the installation is restricted the engineer may be forced to reduce the watts per square foot in order to keep within a given appropriation. It should be mentioned that all figures are based on the supposition that good scientifically designed reflectors are used.

It is possible from the foregoing to lay out a set of simple rules which may be serviceable.

1—Measure up the location, making a rough sketch of plan and elevation showing ceiling or roof trusses, positions of windows, obstacles which may affect the installation, present outlets and switching if any, and giving full dimensions.

2—Make a note of color and condition of walls, ceiling, furniture, machinery and equipment as well as the class of work carried on and the closeness of application required.

3—a—Draw up plans to scale.

b—Decide on the lamp size and mounting height.

c—Assumed the watts per square foot to be used.

d—Deduce the ideal spacing distance—$d = \frac{W}{w}$.

e—Lay out positions of lamps on the plan, to give regular spacing distances, installing a r ow within two feet, nine inches of each wall if an office, and a pproximating, as near as possible, to the ideal spacing distan ce in both directions.

f—Make a tracing, from the plans, showing boundaries of the area and positions of lamps and old outlets, if any, also switching.

g—Specify size of lamps and reflectors, mounting height and any other information dee med necessary for the assistance of the wiremen.

h—Show control of lamps by numbering all on one switch the same.

4—Check up the design at the actual location to see that each lamp is effective and free from all possible obstacles.

The above rules suffice for the calculation and design of adequate illumination for the majority of cases which are likely to come under consideration in a modern industrial establishment. It should also be remembered that standardization as far as possible in every direction will tend to cheapen the installations by simplifying the work of the designer, the wiremen and those responsible for the maintenance.

The application of the above rules to one or two particular cases may, perhaps, be of further interest:—

Example 1—It is proposed to light a building, an end elevation of which is given in Fig 2. The height of the roof truss, in the center aisle is 16 feet and the roof at the walls is 11 feet high, rising to 12 feet toward the center, and being supported on T beams.

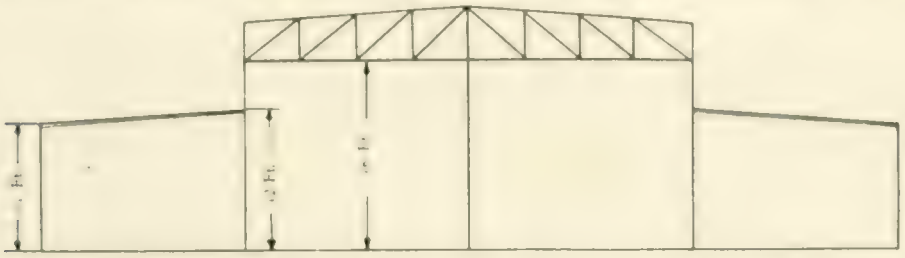


FIG. 2—END ELEVATION OF FACTORY BUILDING.

The location is used for general manufacturing purposes which, however, are not so fine as to necessitate the use of special or individual illumination. The walls are white and the ceiling or roof, a dark color. The size and shape are shown on the plan in Fig. 3. There are no obstacles, except columns, which will interfere with the placing of the lights in any desired position.

The height of the roof trusses in the center is 16 feet and from Table I, for mounting heights of between 11 and 16 feet, 100 watt lamps are suitable. It is therefore decided to use 100 watt lamps and mount them 15 feet from the floor which is within a foot of the stringer boards. Similarly 60 watt lamps mounted 10 feet above the floor are deemed best for the side aisles. It is only necessary to consider a general scheme of lighting since no particular spot needs special illumination. One and one-half watts per square foot is the figure given in Table II, for an average manufacturing area

and, taking into account the effect of the surroundings, it will be advisable to work with 1.4 watts per square foot. The lamps will be mounted on stringer boards and each 100 watt light will cover an area of $100 \div 1.4 = 71.5$ square feet, giving a spacing distance of $\sqrt{71.5}$, or 8 ft., 6 in. Each 60 watt light will similarly cover an area of 43 square feet, giving a spacing distance of 6 ft., 7 in.

Trying out the spacing distances on the plan for the 100 watt lamp commencing at the south wall, Fig. 3, and leaving 2 ft., 6 in., it

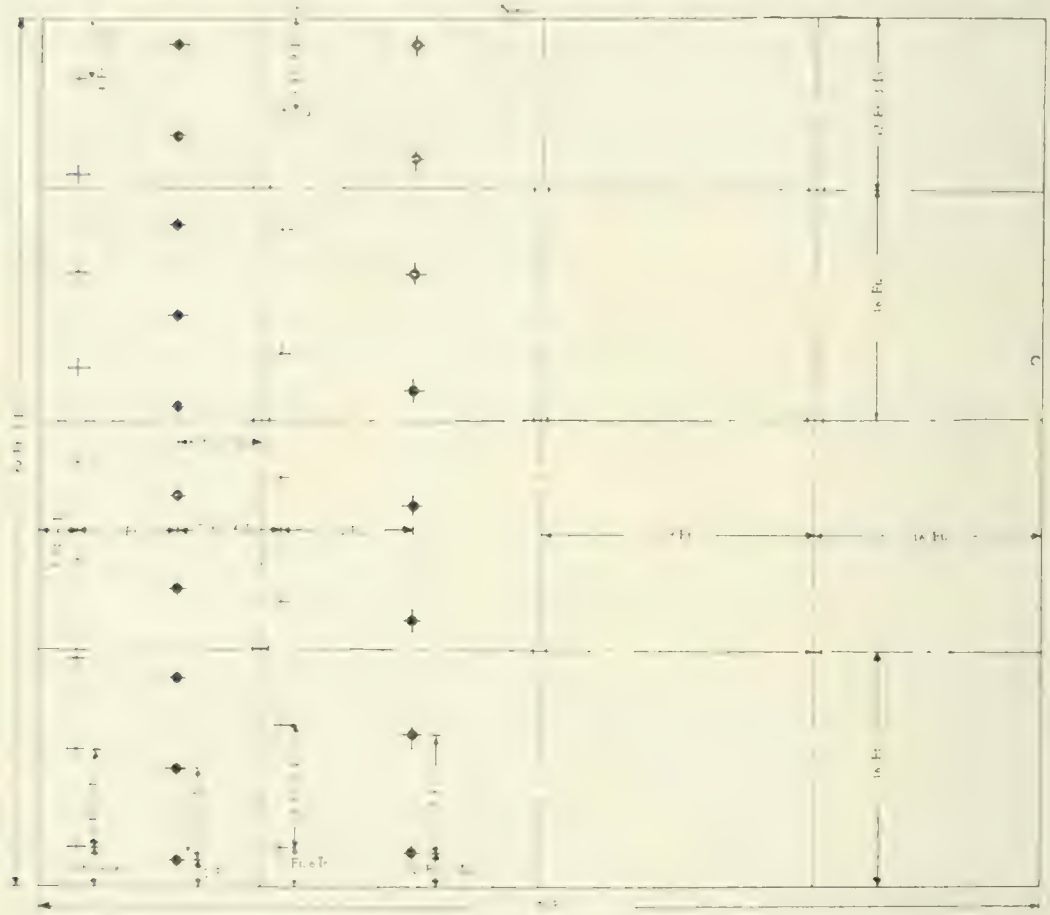


FIG. 3—PRELIMINARY DIAGRAM OF LAMP SPACING DISTANCES IN FACTORY LOCATION

is found that 8 ft., 6 in. gives too large a space at the north end as shown from *a* to *b* (6 ft., 9 in.) while 8 ft. gives 2 ft., 1 in. at each end, which although rather a short distance is permissible and will allow of benches being placed against the end walls. On the plan (Fig. 3) the crosses + show the positions of the lights for a trial spacing distance of 8 ft., 6 in., commencing 2 ft., 6 in. from the south wall, while for 8 ft. spacing distance the lamps are marked in the usual way. Keeping to the same area per light, i.e. 71.5 square

feet the spacing distance in the other direction, side to side, will be $\frac{71.5}{8} = 8.9$ or 9 feet, the lights being therefore at the corners of a rectangle eight feet by nine feet. The 100 watt lights are to be preferred to the 60 watt for lighting manufacturing areas owing to their greater mounting height and spacing distance, while still giving excellent distribution, and so a row of 100 watt lights near the junction of the high and the low aisles is desirable. The spacing dis-

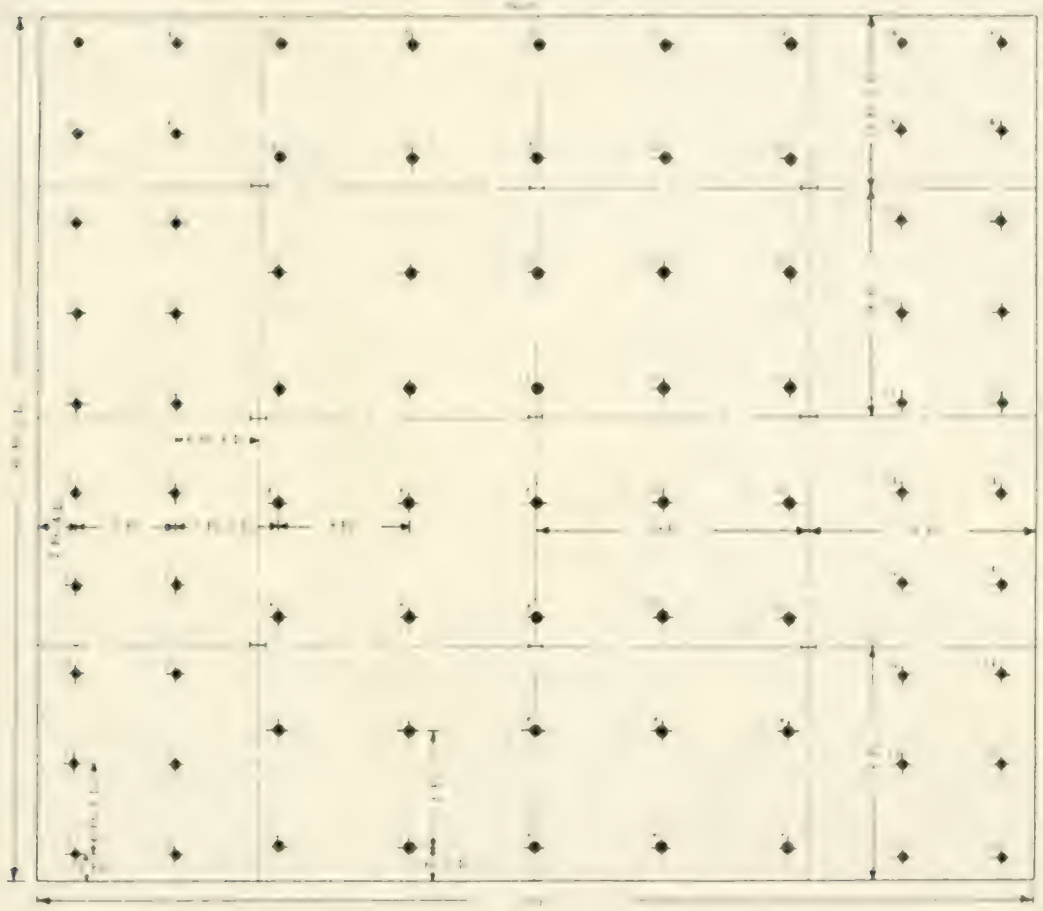


FIG. 4—COMPLETED DIAGRAM OF LAMP LOCATIONS

tance decided on brings a row within one foot of the junction on either side. These will be mounted 13 feet high in order to throw the required light on the side aisles.

Proceeding with the 60 watt lights in the same manner, the ideal spacing distance (6 ft., 7 in.) stepped off throughout the length of the building, leaving 2 ft., 6 in. at one end, gives 6 ft., 4 in. at the other end. By trial it is found that 6 ft., 3 in. brings the end rows within 2 ft. from the walls and hence this distance is taken. The spacing distance in the other direction will be $43 \div 6.25 = 6.88$ or 7 feet. Hence, taking one row of lights 2 ft., 6

in. from the side wall and the next row 7 ft. away from the first we are left with a distance of 6 ft., 6 in. to the junction of the aisles and 7 ft., 6 in. to the nearest row of 100 watt lights. The ideal distance between 100 watt and 60 watt lamps would be $\frac{6 \text{ ft., } 7 \text{ in.} + 8 \text{ ft., } 6 \text{ in.}}{2} = \frac{15 \text{ ft., } 1 \text{ in.}}{2} = 7 \text{ ft., } 6\frac{1}{2} \text{ in.}$ There is thus uniform distribution throughout the area and the design is complete.

The layout is then made as shown in Fig. 4, it being noticed that all lamps are free from the columns. There are forty 100 watt lamps and forty 60 watt lamps or a total of 80 lamps, which use 6 400 watts, giving $6\,400/4212 = 1.5$ watts per square foot over the whole area. This figure is higher than that planned (1.4) for the individual lamps but this is owing to the lamps near the walls. The switching of the lamps is indicated by the numbers on the plan, all lamps of the same number being on one switch.

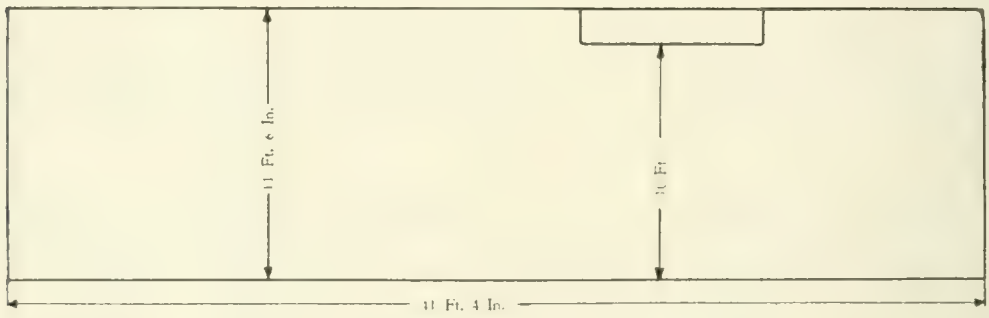


FIG. 5—ELEVATION OF OFFICE LOCATION

Example 2—An office has a ceiling 11 ft., 6 in., high and both it and the walls are light colored. The room is used for clerical work and filing, the area being 41 ft., 4 in. by 43 ft., 9 in., equalling 1 810 square feet. A ventilating duct causes an obstruction, as shown in Fig. 5, the bottom being eighteen inches below the ceiling.

The effect will be best if all the lamps are mounted with the top of the reflectors level with the bottom of the air duct. This gives a mounting height (which is always measured to the socket) of ten feet. Proceeding as in the former example, it is decided, upon referring to the Table I, to use 60 watt lamps, the watts per square foot being chosen as 1.4, modified owing to light ceiling and walls to 1.3. The ideal spacing distance, calculated out as explained, is 6 ft., 8½ in. Laying out the lamps it is found that in a direction east to west, a spacing distance of 6 ft., 5 in., places them free from obstructions and leaves 2 ft., 7½ in. at each wall. In the other direction the width of air duct is 7 ft., 6 in., which makes 7 ft., 8 in. the minimum distance apart that the two rows of lamps can

here be spaced. Thus placing one row of lamps as near as possible to each side of the duct and laying out the rest of the system, a convenient spacing distance is found by trial to be 7 ft., 2 in., and this figure is adopted, the row of lamps nearest the walls being 2 ft., 6 in. distant therefrom. The general spacing distance is 7 ft., 2 in. by 6 ft., 5 in., = 46 square feet, (Fig. 6) giving $60/46 = 1.3$ watts per square foot for each lamp and for the whole area the figure is found

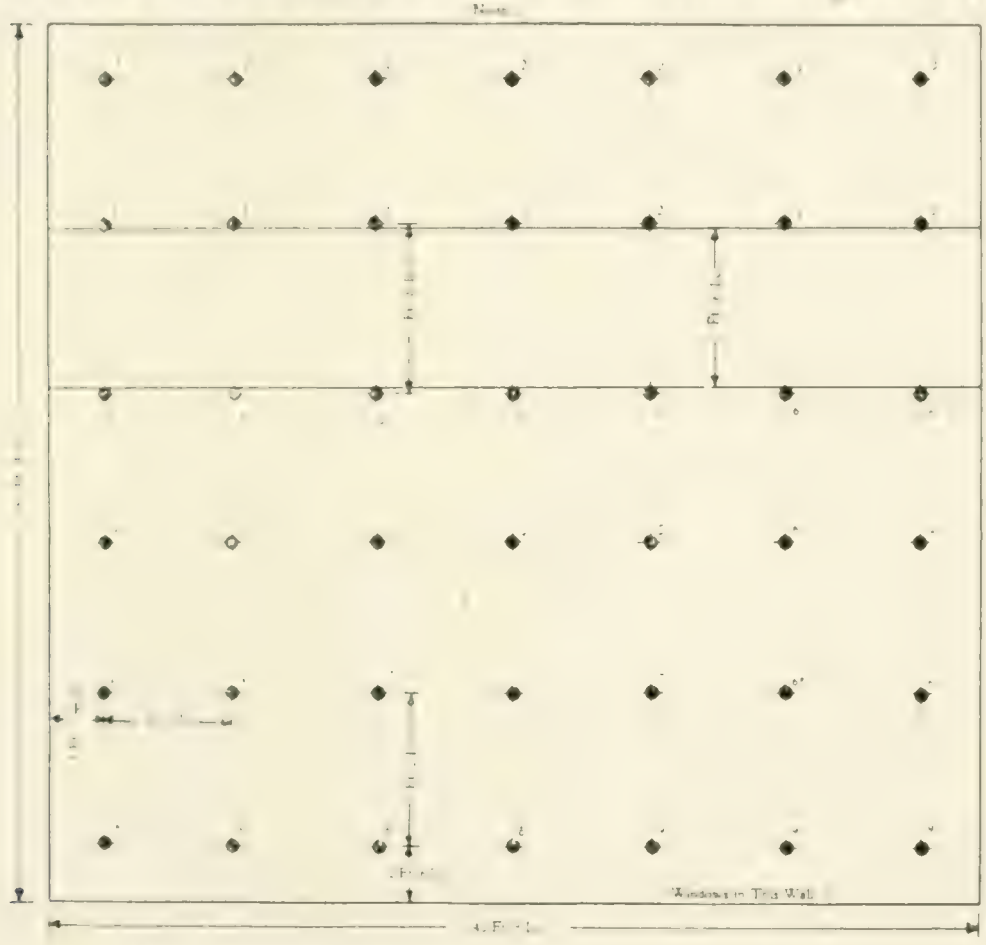


FIG. 6—DIAGRAM OF LAMP LOCATIONS OF OFFICE ROOM, CORRESPONDING TO FIG. 5

to be $\frac{42 \times 60}{1810} = 1.4$ watts per square foot. With light ceilings and walls, and good reflectors, this amount of illumination will be sufficient for average requirements.

Where the ceiling heights overlap, the size of lamp is finally decided by the relation of spacing distances to the dimensions of the room. For the sake of standardization, the number of sizes of lamps used may be reduced to four as shown in the right hand half of Table I.

TRUNK LINE ELECTRIFICATION*

N. W. STORER

THE SUPPLYING of motive power is one of the most important elements of railway transportation. For many years the steam locomotive had a complete monopoly of the business and, like some other monopolies, it lacked the incentive of competition. Since the electric locomotive entered the field, however, there appears to have been a great awakening among steam locomotive designers. The improvements in the steam locomotive, such as mechanical stokers, superheaters, smoke consumers, etc., have lead to the production of the enormous units that are now standard. These great machines have produced such excellent results that the electric locomotive no longer has such comparative advantages as were apparent even ten years ago; and, while the electrification of a large part of our railways will undoubtedly be accomplished at some time, the improvements in steam locomotives have removed the crying necessity for it, except in special instances. It would be a great mistake to compel the railways to electrify too rapidly; it would be far better for them to study the subject with the greatest care, and finally to unite on the best system and then proceed with electrification in places where there will be distinct economic advantages. In large cities especially, it is of the utmost importance that the railways unite and give every plan most careful consideration before starting actual work.

The manufacturing companies have done a tremendous amount of work in developing the various systems of electrification, and in the design of electric locomotives. They have learned many things about locomotives. They have found that low center of gravity in the electric locomotive, instead of being an advantage, is a decided disadvantage. They have also found that because an electric motor develops its power by rotation it is not necessarily easy for it to turn the wheels of a locomotive. For some years it has been recognized that one of the greatest problems in the electric locomotive is the transmission of the torque of the motor to the driving wheels. There have been a great many combinations proposed and quite a large number of different types have been built, and are now in operation, but there are few transmission systems that are absolutely satisfactory from all points of view.

In this respect, as in most others, every design is a compromise among the conflicting elements, not simply in the locomotive

*From a paper read at the annual convention of Association of Railway Electrical Engineers, Chicago, October 24, 1912

itself, but on the roadbed and shop as well. It is recognized that, in proportion as a locomotive is built up around one idea in its design, it will be distorted, and other things will be neglected. It is, therefore, necessary that a careful study of the entire problem of railroading be made in order to produce the best type of locomotive. Progress in heavier railway electrification is analogous to that of the development of street railways. The early forms of railway motors and controllers were designed, to a great extent, in the laboratory; but as time went on the designers became more and more imbued with the spirit of the operating man and with the problem in general, and from the constant association with those men and the study of the problems in the field, they developed street railway motors and controllers to their present high state of perfection. The same plan should be followed in connection with the electrification of railways. The best locomotive is the one that will deliver the transportation required of it with the lowest sum total of expense. This must include not simply the first cost and cost of maintenance and depreciation of the locomotive itself, but the first cost and cost of maintenance, depreciation and operation of the entire installation from power house to roadbed.

The standard type of single reduction geared motor has been eminently satisfactory for street car service, but the difficulties connected with it have increased enormously as the power of motors and speeds have been increased, until today it is considered poor practice to gear locomotive motors directly to the axles, except for slow-speed work. Several reasons have contributed to this belief: —

1—The gears are subject to very severe service when run at high speeds and rigidly connecting so much inertia as is contained in the wheels and armatures, and to still greater shocks from the roadbed. In the operation of high speed railways using single cars or multiple-unit trains, there has always been more or less trouble from gears with speeds around fifty and sixty miles an hour. The gears and armatures both suffer and there is always a great increase in the cost of operation, especially if the track is poor.

The motor on one axle is subjected to worse punishment than on the other. The trailing axle has the pinion of the motor pushing downward on the gear teeth, and the other axle has it pushing upward. The motor whose pinion is driving downward usually suffers much worse both in gears and in the armature windings, due to the blows that it gets from the roadbed. When a wheel comes to a depression in the track, it is suddenly lifted as it climbs out,

and gives a direct shock to the teeth of the gear, that tends to retard the whole armature.

2—The weight of the motor on the axle, and its low center of gravity, contribute to serious injury to the track when operated at high speeds. Chiefly for these reasons, the speed of most locomotives, having heavy motors geared directly to the axles, is limited to about 30 miles per hour.

This geared type of locomotive is comparatively simple, cheap and easy to maintain, but when the design of a locomotive for high speed service is considered, the problems to be solved are many and difficult, and the solutions that have been offered are almost as numerous. It is of course comparatively easy to design motors that are sufficiently large and powerful to equip any locomotive that is desired. The big question is, how to connect the motors to the driving wheels so as to give a locomotive that will have a reasonable cost of maintenance and, at the same time, be a good riding machine.

There are several general types of high speed locomotives:—

1—Those with armatures mounted rigidly on a driving axle.

2—Those with motors mounted on a quill surrounding the axle.

3—Those with motor geared to quill surrounding axles, and connected to wheels through long helical springs.

5—Those with motors mounted in the cab and driving through a jack shaft and a system of parallel rods.

5—Those with motors mounted low between frames and connected to the drivers through a Scotch yoke.

6—Those with motors connected to the wheels by some combination of gears and side rods.

ARMATURES ON DRIVING AXLES

The first type, known as the New York Central type, may be called an example of a locomotive built around one idea, namely, that of mounting the armature of the motor directly on the axle, and building the motor field into the truck frame so as to do away with all motor bearings. It is a scheme that is ideal in its simplicity, and it is not surprising that the New York Central desired to use it. However, it is well known that the locomotives have never been considered as successful high speed machines, on account of the tendency to nosing. Many steam locomotives have some tendency to nosing, but it is not serious, as the mass of the locomotive is located so high above the rail that the wheels may follow any tive, and consequently, with the minimum of strain on the rails. This type of electric locomotive has an extremely low center of

gravity, so that it is quick to feel the irregularities in the track, and synchronous vibrations are very easily set up. A great deal has been done to eliminate this defect, but the efforts have been only partially successful.

ARMATURES MOUNTED ON QUILLS SURROUNDING AXLES.

This type, first used on the New Haven passenger locomotives, has the motors mounted on quills surrounding the axles and connected through springs, and is open to some of the same objections as the first type. It also has a low center of gravity, although considerably higher than the first type, but all weight is spring-supported so that the track does not get a direct blow. The original New Haven locomotives nosed at high speeds, but this was cured by the addition of idle wheels at each end of the locomotive and a toothed cam centering device between the cab and the trucks. However, even with the motors carried by springs, the track is liable to damage unless it is kept in good surface.

MOTORS GEARED TO QUILL—USE OF HELICAL SPRINGS

The third type is one of the latest developments, and the New Haven and Boston & Maine locomotives of this type are the easiest riding electric locomotives that have been built. Mounting the motors rigidly on the trucks above the axles and gearing down to the quills, of course raises the center of gravity very considerably. Then the long helical springs connecting the quills to the driving wheels permit the axles and journal boxes to move a total vertical distance of three inches in the pedestal jaws, before the quills touch the axles. Then the wheels are free to follow the inequalities of the track without disturbing the mass of the locomotive, and consequently with the least possible damage to the track. The arrangement of wheels, combined with the distribution of weight and the drive, entirely prevents nosing, and the secondary springs, transmitting the weight of the cab to the trucks through the large surface plates, prevent the transmission of vibration from the truck frame to the cab.

This type of locomotive has been built, both with a single motor per axle, and with twin motors of the same total capacity per axle. After building a number of the former, whose motors were so large as to require double gears, it was found that the same output could be obtained, with less weight and less cost, by substituting two motors for the one large one. This arrangement has the following advantages:—

1—Only one gear is required, as both motors drive through the same gear.

2—The two motors are lighter and easier to handle, and cheaper to maintain than the large one.

3—The motors in this case may be made interchangeable, except field casting, with the motors used on multiple-unit cars.

4—Two motors permanently connected in series gives in effect one motor of double voltage and consequently half current. This reduces the carrying requirements of cables and switches to one-half, and thus makes a substantial saving in the cost of control equipment.

The spring drive eliminates the bad effects of the impact of the teeth when operating at a high speed, so that it is anticipated that the gear speed may be much higher than that of ordinary gears mounted directly on the axles.

While these locomotives are now built for single-phase operation, they would have practically the same advantages on direct current. The twin motor scheme adapts itself well to high voltage direct-current operation.

MOTOR DRIVEN THROUGH JACK-SHAFT AND PARALLEL RODS

The fourth type of locomotive has a very high center of gravity and, although the weight on the driving axle is about 56 000 lbs. and the springs are consequently stiff, the locomotive has excellent riding qualities. There is no tendency to nosing, and no bad effects on the track. The first locomotives of this type were those for the New York terminal of the Pennsylvania Railroad. These are the most powerful electric locomotives ever built, and have a record for the first year, with 33 locomotives in service, of 13 train minutes delay chargeable to the locomotive. They have developed over 75 000 lbs. tractive effort at the draw-bar. This corresponds to a crank-pin pressure of over 100 000 lbs. Of course, the normal pressure on crank pins is not nearly so high, but it is sufficient to impose strains on the jack-shaft bearings that are very hard to hold. These strains are worse than on reciprocating engines. There is scarcely any neutral zone, because of the combination of strains imposed upon it by the motor rods and driving wheel rods acting at an angle of about 45 degrees from each other. This angle, however, is much to be preferred to the vertical motor rods adopted for the first locomotives built for the German State Railways. These were practically failures, and it is understood that future locomotives will have motor rods similar to those of the Pennsylvania.

The use of side rods on an electric locomotive introduces some different problems from those found in the steam locomotive. As there are no reciprocating parts, such as piston rods, the parts are susceptible to perfect balance. The rods must be much larger than for corresponding steam locomotives, because the entire power has to be transmitted through one set of pins and rods at certain points in the revolution, while the steam engine transmits the power from only one cylinder. The steam engine has another advantage in that the main rods on the two sides of the locomotive are connected to loose ends (pistons), while the rods on the two sides of the electric are connected to opposite ends of the motor shaft, as well as the jack-shaft, which introduces a great many chances for inaccurate workmanship and consequent knocking in the pins and bearings.

MOTOR CONNECTED TO DRIVERS BY SCOTCH YOKE

The fifth type of locomotive has been used exclusively for the threephase locomotives on the Italian State Railways. The first ones have been in service some 10 to 12 years on the Valtellina line, and have given excellent results. The later ones, some 35 in number, have been used about two years on the Giovi line near Genoa. These machines have some excellent qualities,—light weight, powerful motors, and motor weight entirely spring supported. They have, however, been used only in slow and moderate speed service, so their performance at high speed remains to be proven. These locomotives also require very accurate adjustment, although not so close as the ones with side rods and jack shafts, as the Scotch yoke drives one axle through a sliding block and the others through parallel rods connected to the yoke by knuckle-pins.

MOTORS CONNECTED BY COMBINATION OF GEARS AND SIDE RODS

A number of locomotives of this kind have been built, the most notable being those built for the Loetschberg Tunnel in Switzerland, and for the Midi Railway in France. The former has two 1 000 horse-power motors, each connected by a helical tooth gear to a jack shaft, which is slightly above the driving axles, and thence by parallel rods, to three pairs of driving wheels. Although the motor speed is extremely high, the gears operate practically without noise and with high efficiency. The duty on the jack shaft bearings is much easier than when side rods only are used, since the reciprocating pressures are practically all in a horizontal direction, and can therefore be cared for much more easily. The Midi locomotive has two motors, each geared to a jack shaft through gears located outside the plate frames of the locomotive. The jack shafts are con-

nected to the drive wheels through Scotch yokes, like the Italian locomotive. Either of these types has fairly high center of gravity and is therefore susceptible of a design that will have excellent riding qualities.

Any of the types of locomotives described, except the New York Central type, might be equipped with apparatus for any of the known systems. The New York Central type is suitable for direct current only. The New York, New Haven & Hartford locomotives, of both types described, are operated with single-phase alternating current motors on both alternating and direct-current circuits. The Pennsylvania locomotive is for direct current, but locomotives of similar type are built in Germany for single-phase lines. The Italian locomotives are all for three-phase operation. The combination gear and side rod locomotives are both equipped for single-phase operation.

While most of these locomotives are equipped with alternating-current motors, this is only because it has been believed that alternating current is better suited for heavy trunk line electrification.

OTHER CONSIDERATIONS IN THE CHOICE OF A SYSTEM

If the choice of system rested only on the locomotive, undoubtedly the standard 600 volt direct-current system would be chosen in the large majority of cases as being the simplest and best adapted for the work. But for the electrification of a trunk line, this is an economic impossibility, because with the low voltage too great an expenditure for substations is required and a low efficiency results except with a traffic which gives a good load factor. Third rails must be used on account of the enormous currents required.

In order to reduce the number and cost of substations, the voltage must be increased to a point that would prohibit the use of a third rail, even if it were not otherwise undesirable. It is therefore generally accepted as a fact that the current must be taken from an overhead trolley. It then becomes a question as to how much current can be collected from an overhead conductor. At slow speeds 150 to 200 amperes can be collected with an ordinary trolley wheel. As much as 400 or 500 amperes can be collected for a few seconds. A current of 200 to 300 amperes may be collected continuously at high speeds, either by wheel or some form of roller or sliding shoe. The wheel can scarcely be considered, but both roller and sliding pantagraph trolleys have been used.

It is of the greatest importance to have the overhead construction very flexible and to have the current collectors light. Other-

wise there will be flashing, and the trolley will become kinked at every suspension point so that it will soon break. It is also undesirable to increase the number of collectors. All of these things tend to limit the amount of current that can be collected for a single train, and consequently render an increase in voltage necessary.

Locomotives of over 3 000 horse-power capacity have been designed, and it will probably be necessary at times to operate two such locomotives in a single train. Even with one of them operating at rating, a current of about 750 amperes would have to be collected with a voltage of 3 500 volts direct current. Granting that two collectors might be used, the current per collector would still be close to, if not beyond, the range of anything that has been successfully accomplished up to the present time in high speed service. It is believed that 3 500 volts direct current is about the lowest voltage that should be considered for high speed trunk line service, on account of the difficulties of current collection. Lower voltages may, of course, be used for lighter and slower service. Whether locomotives can be made commercially with this high voltage, remains to be determined. Even if locomotives were built, however, it is very certain that such a voltage is entirely beyond the range for multiple unit-car operation, so that any line operating at 3 500 volts direct current would be confined to locomotive service.

The single-phase system is the only one that has successfully solved the problem of current collection at high speeds. The usual voltage for heavy railway work in this country is 11 000. In Europe it is even higher, 15 000 for the Loetschberg tunnel line, and this will probably also be used in Germany in the electrification of the State Railways. Either voltage makes it a comparatively simple matter to collect current for the heavy high speed trains.

The New York, New Haven & Hartford Railroad, which is using the 11 000 volt single-phase system, is steadily extending its electrification. It is practically the only company that is making such extensions. They have the Oak Point yards and the Harlem River division equipped now and are doing their switching with electric locomotives. They have suburban service on the New York, Westchester & Boston Railway, and they are rapidly extending the main line electrification to New Haven, so that in a very short time they will run from New York to New Haven with electric locomotives. At the same time, they are figuring on the line from Boston to Providence which will probably soon be electrified. Such extensions indicate that the system is satisfactory.

THE VIBRATING RECTIFIER

A DEVICE FOR MECHANICALLY CHANGING ALTERNATING CURRENT OF STANDARD VOLTAGE TO LOW VOLTAGE DIRECT CURRENT

Q. A. BRACKETT

THE general adoption of electric lighting on gasoline automobiles is mainly accountable for the large number of three-cell storage batteries that are now being employed in the automobile industry. Such lighting requires a source of current, such as storage cells, which will be more continuous than can be obtained from dry batteries, of more uniform voltage than can be obtained directly from a small dynamo driven by the engine, and which, unlike the dynamo, will continue to light the lamps when the engine is not running. General practice seems to have settled on a standard of three lead cells, furnishing current at six to eight volts. Such batteries require charging at intervals depending upon the ampere-hour capacity and how much the lights are burned. Of course if the owner has direct current at his disposal he can charge his battery by putting a suitable number of incandescent lamps in series with them but, while this is simple, it is likewise very inefficient as over 100 volts must be used up in resistance in order to obtain from the 110 volt circuit the six or eight volts required for the battery.

Most automobiles owners, however, live where only alternating current is available. In such cases the only recourse thus far has been to leave the battery at a garage to be charged over night and called for the next day. This is decidedly inconvenient unless a spare battery is kept on hand so that the car will be available at all times, including these trips to and from the garage. The cost of having this small battery charged at a garage is, moreover, out of all proportion to the real value of the energy put into the battery. This is because the garage owners usually have no efficient way of charging such a small battery, and besides usually take the stand that it is just as much trouble to charge it as a large electric vehicle battery. It is rare that the cost for charging an ignition battery is less than $1.00 per charge, and it is often $1.50.

Where alternating current, such as is used for ordinary electric lighting, is available such difficulties may be avoided by the use of a device which has recently been developed, known as the vibrating-type rectifier, a simple, efficient and inexpensive piece of apparatus which is adapted particularly to the charging of three cell automo-

bile ignition batteries. This rectifier, which is illustrated in Figs. 1 and 2, promises to be both a great convenience and a source of very material economy to automobile owners. It is essentially an electrically operated vibrating switch, which reverses the connection of the alternating-current line to the battery in synchronism with the alternations of the current, this reversing action being accomplished at the moment when the current flow is zero. The rectification is thus accomplished without sparking at the contacts, and results in the delivery to the battery of an intermittent, pulsating current uniform in direction. When thus supplied with uni-directional current the battery is charged exactly as though a constant voltage direct current were applied. The shape of the rectified current wave and its relation to the original alternating-current wave are indicated in Fig. 3.

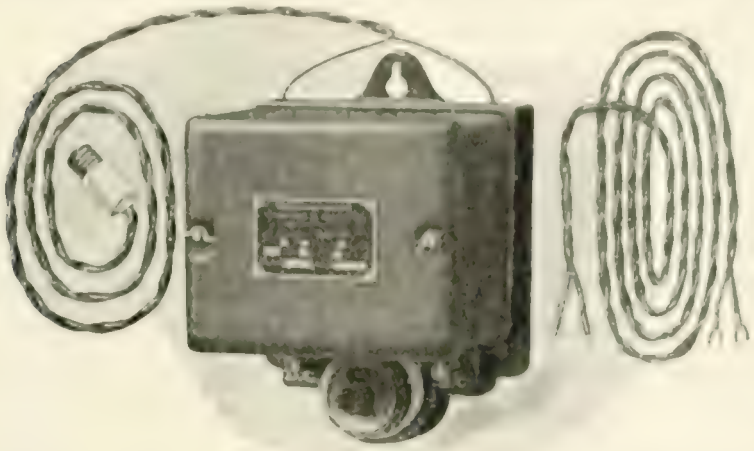


FIG. 1—EXTERNAL VIEW OF VIBRATING RECTIFIER COMPLETELY EQUIPPED FOR USE

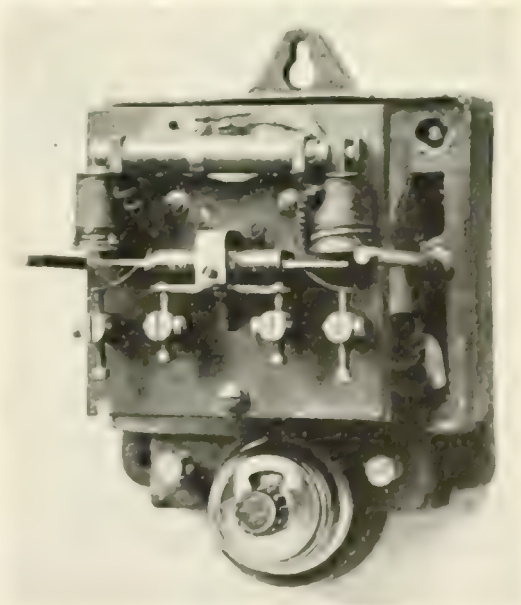


FIG. 2—VIBRATING RECTIFIER WITHOUT COVER

The principle on which the device operates can be best understood by reference to Fig. 4, where it will be seen that the movement of the vibrating switch is controlled by magnetic means. A small two-winding transformer serves to reduce the alternating-current line voltage to the proper value for charging three lead cells. Across one-half of the low voltage winding are connected the two alternating-current magnets, which, while electrically in series, are magnetically in opposition to each other. That is,

each presents the same magnetic polarity to the pivoted armature at any given instant. During one-half wave of the alternating current each magnet presents, say, a north pole to the armature, while during the next half wave each presents a south pole. There is a winding upon the armature also which receives direct current from the battery being charged. This causes one pole of the armature to be north and the other to be south continuously, so long as the battery remains connected to the rectifier. Inasmuch as a north magnetic pole tends to attract a south and repel a north pole, the alternating-current magnets attract one end of the armature and repel the other at a given instant. Each time the alternating-current reverses the opposite end of the armature is attracted and it swings accordingly on its pivot support in synchronism with the alternations of the current. The amplitude of vibration is controlled by springs at each

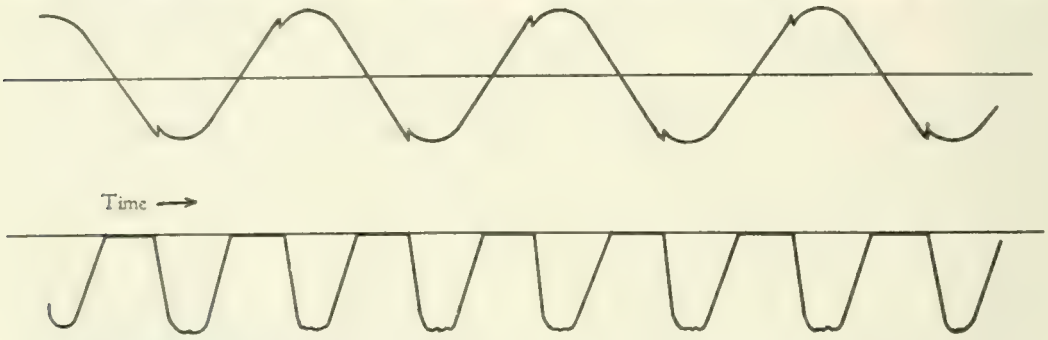


FIG. 3—OSCILLOGRAM OF IMPRESSED VOLTAGE AND CHARGING CURRENT
The sharp break in the voltage wave does not exist in the impressed wave, but is caused by the drop in potential at the instant the current starts.

end of the armature and these likewise serve to render the vibrations smooth, uniform and positive. The moving contacts are themselves mounted on springs whose compression, when contact is made, prevents any tendency to bounce, and likewise allows the contacts to remain together the length of time necessary for the proper charging current to flow. The armature carries near each end a platinum contact opposite each of which is mounted a platinum tipped screw. As the armature vibrates contact is made, first on one side and then on the other. As shown in the diagram, the two ends of the low voltage winding of the transformer are connected to the two contact screws while the middle point of the armature is connected to one of the two binding posts which serve as terminals for the connection of the battery to be charged. The other battery binding post is connected to the middle or "neutral" point of the low voltage winding of the transformer. Accordingly

when the armature is attracted in one direction the current flows from one end of the transformer secondary across the platinum contacts that are then together, out through the middle point of the armature into the battery, and back to the neutral of the transformer. When the alternating current reverses and the armature is attracted the other way the current flows from the other end of the transformer secondary winding across the other pair of platinum contacts and thence through the battery in the same direction as before. This action gives the intermittent, uni-directional current through the battery.

A valuable feature of this arrangement is that it makes no difference how the battery is connected to the rectifier and no attention need be paid to polarity, as the outfit will automatically deliver current to the battery in the right direction no matter which way it is connected, since if the battery connection is reversed the polarity of the direct-current armature is thereby also reversed.

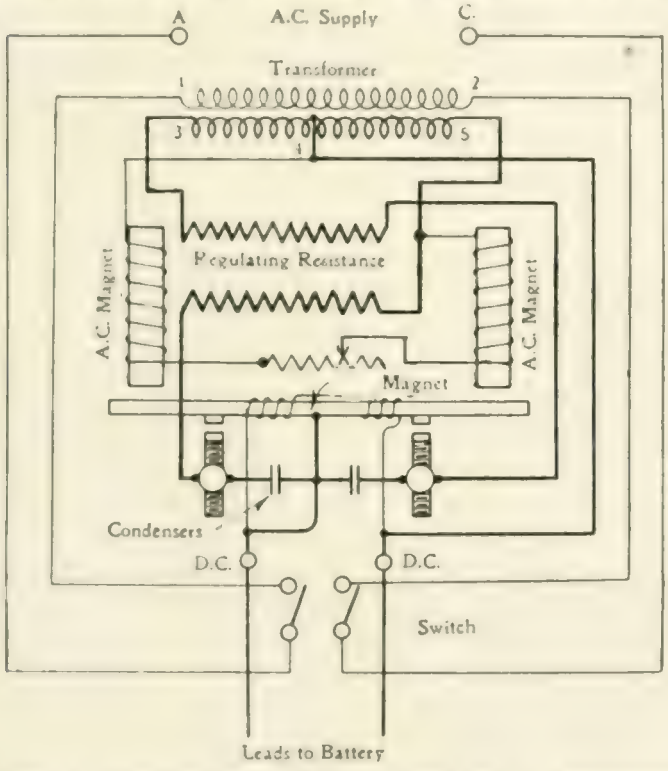


FIG. 4—WIRING DIAGRAM OF VIBRATING RECTIFIER
The method of exciting the direct-current magnet makes wrong connection to the battery impossible.

A vibrating rectifier, to be a success, must not only deliver direct current but it must do it practically without sparking; otherwise, long life of contacts and freedom from the necessity of readjustments will not be obtained. To accomplish this, the motion of the armature must be so timed as to break contact just at the right instant, that is, when the current is passing through zero, as shown in Fig. 5, where *A* is the wave of alternating voltage and *B* shows the second half wave inverted or "rectified." *C* is the voltage of the battery and *O* is the line of zero voltage. Only that portion of the

alternating-current wave which lies above the line of battery voltage is effective in charging the battery. If the rectifier is to operate properly it should make contact at point *D* or some higher point on the alternating-current wave and break contact at point *E* only. If it makes contact at any point between zero and *D* a reverse current will flow from the battery into the rectifier, tending to discharge the battery. If it makes contact at *D* or some higher point the current will flow into the battery as desired. The effect of making contact too soon is, therefore, to reduce the output of the rectifier by allowing an initial reverse current to flow that partially nullifies the good effect of the later current in the right direction. The effect of making contact late is to reduce the output by not utilizing all of the available alternating-current wave. Neither making contact early or late, however, has any effect on the sparking, which is dependent only on the time of breaking contact. If the break occurs just at the point *E*, the current at that instant will be zero and no sparks will occur when the contacts separate. If, however, the break occurs at some point above *E* the current will still be flowing into the battery, or if at some point below *E* it will have reversed and will be flowing out of the battery, and in either case sparking will result. Accordingly it is necessary that the rectifier be adjusted by the manufacturers so as to break contact when the current is zero and so operate sparklessly. But to make assurance doubly sure and to guard against unusual conditions, suitable condensers are connected across each pair of contacts, as has long been the practice on induction coils, for instance, to absorb any sudden rush of current when the contacts open and so prevent what little sparking might occur. During the period between *E* and the next succeeding *D*, the vibrator has broken contact on one side and has not yet made contact on the other. As both pairs of contacts are therefore open there is no current flowing in the battery. This period of zero charging current is plainly shown in the oscillogram, Fig. 3.

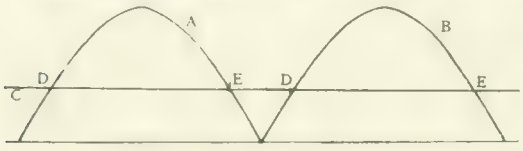


FIG. 5—DIAGRAM OF RECTIFIED ALTERNATING VOLTAGE WAVE AND BATTERY CURRENT

If the rectifier is used on an alternating-current circuit whose wave form differs very much from a sine wave it may be necessary to change the adjustment slightly to eliminate sparking. This is because the time of zero current may come a little earlier or later

than in the corresponding sine wave. If this involved any delicate change of springs or contacts, such an adjustment would be an undesirable, even though necessary, feature; but fortunately it is simply necessary to slide a contact along a small resistance mounted in an easily accessible place at the rear of the vibrator until the point is reached where sparking has ceased. This resistance is connected in series with the stationary alternating current magnets and serves to shift their phase angle, that is, to vary slightly the time at which they reach their maximum strength during each half wave of the alternating current and, accordingly, the time at which the contacts break. This single adjustment is very simple and can be used to make up for wearing away of the contacts as well as for adapting the operation to unusual wave shapes.

Small size and simplicity of operation are two of the marked advantages of the vibrating type of rectifier. Because of its small size it can be placed upon a table, hung on a nail on the wall or carried around in the tool box of an automobile. An attachment plug and cord for the alternating-current side and a pair of battery leads for the direct-current connection are included with the outfit. It is put in operation simply by screwing the adjustment plug into a 110 volt lamp socket, connecting the rectifier to the battery, (paying no attention to polarity) and turning on the switch. The rectifier will start up automatically and in case the line voltage is interrupted during charge it will stop on open circuit. There is thus no possibility of the battery discharging back through the rectifier, and no elaborate special cut-out switches are necessary to give this protection. When the line voltage comes on again the rectifier restarts automatically. While it may occasionally be necessary to adjust the resistance mentioned above, this is scarcely a moment's work and requires no special skill.

Over and above the features of small size and simplicity, perhaps the most important of all is the fact that the vibrating rectifier now makes it easy for the automobile owner to charge his ignition and lighting battery at home, not only conveniently instead of taking it to a garage, but at such a low cost that he will save himself from $0.90 to $1.40 at every charge. The rectifier costs only about one cent an hour to operate, on the basis of ten cents per kw-hr. for power, and thus it will pay for itself in a short time. It will operate on frequences from 57 to 63 cycles and on line voltages from 100 to 120, limits which cover any conditions that are liable to be encountered on commercial circuits nominally of 60 cycles and 110 volts.

Its direct-current rating is eight amperes, but the actual current delivered may be somewhat higher or lower if the line voltage happens to be other than 110 volts.

In this connection it is an interesting fact that widely different direct-current meter readings may be obtained according to the type of ammeter used. A meter that indicates the average current, such as a permanent magnet type of meter, will show the current that is effective for charging the battery, while a meter that reads the square root of the mean-square current, such as the precision type, will show a current about 50 percent higher, this being the value effective in heating the wires and resistances*. No other ordinary piece of electrical apparatus shows up the difference between average and root-mean square current as markedly as does the vibrating rectifier. This, however, is only one of the many interesting and novel features encountered in the design of this rectifier. The whole problem of making and breaking contact always at the right time, dealing as it does with the instantaneous rather than the integrated values of the alternating-current wave emphasizes many peculiarities of alternating and direct currents not usually appreciated in ordinary electrical work.

Interesting as this is from a scientific standpoint, the really vital fact in the eyes of the automobile owner will be that there has now been developed for his use a small, simple and efficient device wherewith he can charge his own ignition battery at home at a saving of about 90 percent in cost, and eliminate the bother of taking his battery to and from the public garage. This should ensure long-continued and great popularity for the vibrating rectifier.

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*See article by Mr. Paul MacGahan on "The Action of Direct-Current Meters on Rectified Circuits" in the JOURNAL for November, 1909, p. 700; also No. 382 in The Journal Question Box for Feb. 1910.

EXPERIENCE ON THE ROAD

HOW TO UNLOAD AND PLACE A MINE LOCOMOTIVE IN SERVICE

G. W. HAMILTON

In unloading and handling heavy apparatus at the point of destination many important matters require consideration and attention. Some of these may be more or less obvious, but with a complete and consecutive statement of a method of procedure at hand for reference, the engineer in charge of the installation of the apparatus may more readily give forethought to the various preliminaries and precautions which must be looked after. Because of the various principles set forth by Mr. Hamilton in the present article it should interest those who have occasion to handle heavy apparatus whether it be mine equipment or otherwise. [Ed.]

THE locomotive having reached its destination, it is important to unload without delay, placing it either in service or in stock until it is required, so as to release the railroad car promptly. The car should be so set on one of the coal mine sidings that it is near some branch of the surface tracks on which the mine cars are operated, and which leads either to the top of a shaft, to the entrance of the slope or drift, or to the motor barn. Plans should be laid to unload the locomotive so as to use as little time, labor and material as practicable, and to this end the following notes may be used as a guide.

First the brakes of the railroad car should be properly set. After removing the covering placed over the locomotive to protect it during shipment, and having decided whether to unload over the side of the car or over the end, being guided in this decision by the relation of standard gauge track to surface track, the space between the pedestals and the bottom of the main journal boxes must be tightly blocked, using a lever to raise each box, and compressing the journal spring, so that the blocks inserted may be held in place by spring pressure. The locomotive must then be shifted by means of pinch bars and jack until two of wheels are close to the edge of the railroad car, it being borne in mind that in lowering down the slope the locomotive should go front end first and should be so turned before entering the mine.

A block and tackle should then be procured with about 20 feet of rope, at least one inch in diameter. Also provide four sills, each about 6 in. by 8 in. by 8 ft. long, the length depending on the distance from the railroad car to the surface track, and so place them that they will form an incline with one end resting against the ties, sunk into the surface until the top of the timbers is about flush with the top of the surface track rails, while the other is against the side

of the railroad car and flush with the platform or the sills on which locomotive was shipped. The incline should also be supported by good cribbing, the plan being to run the locomotive off the car, over the sills set in position, and onto the surface track. When satisfied that all is ready on the incline, secure one end of the block and tackle to the back draw bar and the other to some stout post or other good support, and slowly work the locomotive down to the surface track, controlling its progress at any point with its own brake and the block and tackle. It is well to thoroughly inspect all details, and be sure that all is clear and clean before making a move on the railroad car, so that no accident can result from anything loose dropping down the shaft when the locomotve is being lowered.

After getting the locomotive on the surface track, it must be hauled or pushed to the top of the hoisting shaft, at the lower landing, after the following questions have been discussed and decided:—

1—If the mine is working daily the work of lowering down the shaft or slope must be done at night, provided a stopping place can be found in ample time before work begins the next morning to take down and clean away any obstructions that have been raised. If this is considered inadvisable it should be planned to start the work on a Saturday afternoon and continue it until finished, which should be before Monday morning.

2—It should be determined whether it is possible to go below ground by way of the air shaft, to assist in the work; if so, the work can be taken care of with about six men in all, not including the hoisting engineer and his firemen.

3—If the locomotive is going into a shaft mine, is the sump deep and wet?

4—What is the size of the hoisting rope?

5—How long has the hoisting rope been in service?

6—What is the weight of the empty cage?

7—What is the weight of a mine car when loaded?

With this data in hand, it will then be possible to decide which of the following courses to adopt:—

1—Lower the locomotive down complete by hanging it below the cage.

2—Lower the locomotive down complete by hanging it at the end of the hoisting rope, the cage having been taken out of the shaft.

3—Hang the locomotive below the cage, but reduce its weight by removing the motors.

4—Hang the locomotive at the end of the hoisting rope, having reduced its total weight by removing the motors.

LOCOMOTIVE HUNG FROM CAGE

In general it is seldom necessary to handle a locomotive weighing more than ten tons after the motors have been removed. The working load for a 1⅛ in. steel hoisting rope in fair condition is eight tons, and the breaking strain 42 tons. With a rope 1¼ in. in

diameter, the working load is ten tons, and the breaking strain 52 tons. Should there be any doubt as to the safe weight, the total weight can be reduced further by removing the wheels and axles, brake work, boxes, etc., though this increases the work of handling, especially at the bottom of the shaft.

The next step will be to send at least two men below to prepare to take the locomotive out of the shaft, the balance of the crew to join them later by way of the air shaft. The first two men sent below will look after the following:—*

1—Set about four 6 in. by 6 in. timbers across the bottom of the shaft above the sump, for safety, and to provide a place to stand if required.

2—Spike between the rails of the mine track, two or three light rails, allowing these extra rails to extend about two feet over the sump, or beyond the end of the mine track.

3—Be provided with about twenty feet of good rope, and see that there is a well-set prop in line with the centre of the track on which the locomotive is to be placed, to which the rope may be lashed.

4—The two men should also be provided with pinch bars, jacks, blocking, etc., that no unnecessary delay may occur.

These arrangements having been made and the men who are going below having been lowered with their tools, those remaining at the top of the shaft should take care of the following details, it being assumed that it is planned to swing the locomotive below the cage:—

1—Have the cage raised about six feet above the level of the lower landing, and while in this position make a final examination of it and the guides, ropes, chains, etc.

2—Attach to the main timbers at the bottom of the cage the chains or ropes with which it is planned to lift the locomotive, having these long enough to permit the locomoitve to swing about six feet below the cage.

3—When the ropes or chains are fastened to the locomotive, not only must they be attached to the draw bar or coupling, but two extra ropes should also be wrapped around the end frame, one at each side, to act as a safeguard, as well as to keep the locomotive from revolving or turning in the shaft.

4—Spike down between the rails leading to the shaft, two to four extra rails, so spaced that the bottom of the locomotive bumper will slide on top of them when being raised.

5—Tighten up the motor suspension, raising the motors above the track as much as practicable.

6—Remove any details which are apt to shake or fall off, and such light details as sand box pipes and rods, headlights, etc.

7—Lay across the top of the shaft two or three heavy timbers, about 8 in. by 8 in., to act as a safeguard should the unexpected happen, and to permit standing over the shaft when necessary.

8—Push the locomotive toward the shaft until the end frame or coupling is flush with the edge of the shaft, and set the brake.

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*The men who go below should go on the cage to which it is planned to hang the locomotive, and when they have gotten off are retained this cage. It should be hoisted to the upper landing. This permits the other cage to reach the bottom, and while there it should be loaded with a car of coal to act as a balance for the hoisting engine when handling the locomotive. When this loaded car has been cut on the cage, it should be hoisted until the other cage, under which it is intended to swing the locomotive, reaches the lower landing, where it should be stopped.

9—Attach the ropes between the locomotive and the cage, and give the signal to the engineer to raise the cage slowly, stopping when they are stretched. The ropes and fastenings should now be adjusted, making certain that the blocks under the journal boxes are in position, after which the brake should be released and the locomotive pinched toward the shaft until the draw bar is under the center of the cage. The brake should now be reset.

10—Station one man to handle the rope controlling the block and tackle, release the brake, and having told the engineer to raise or lower on signal about six inches at a time, start to hoist slowly, pinching the locomotive forward so as to keep the ropes which are lifting nearly perpendicular. When the front bumper commences to bear on the rails which were spiked down as per item *4*, continue to use the pinch bars, until the locomotive has to be held back by means of the block and tackle.

11—When the locomotive hangs steadily over the shaft with the block and tackle hanging from the front bumper, remove the timbers set across the top of the shaft, and give the signal to the engineer to lower slowly and steadily. When all is going smoothly arrange to clean up and re-adjust any details that have been disturbed around the top of the shaft, leaving one man to watch for and transmit signals to the engineer, and let the rest of the men go below via the air shaft.*

When the men below know that the locomotive has left the surface they should carefully approach the bottom of the shaft and watch its descent, being ready to check it with the signal bell at any moment. They should also be prepared to catch hold of the block and tackle hanging from the locomotive and, when it nears the bottom, conduct it toward the rope that has been secured, giving the signal to stop lowering when the front or lower bumper is close to the timbers laid across the sump. The locomotive must be gradually pulled out of the shaft with the block and tackle, alternately lowering a few inches and tightening up the blocks; or, in other words, reversing the operation of swinging under the cage on the surface.

LOCOMOTIVE HUNG IN PLACE OF CAGE

If it is decided that the locomotive is too heavy or too large to hang below the cage, and it is therefore hung on the end of the hoisting rope in place of the cage,† the procedure must be as follows:—

1—Having determined whether the cage shall be taken out at the upper or lower landing, several timbers about 4 in. by 6 in. or 6 in. by 6 in. must first be laid across the shaft, and flush with the top of the track rails, upon which to lower the cage.

2—At the lower end of the hoisting rope two strips of wood about 2 in. by 4 in., or 2 in. by 6 in. with blocks of wood inserted about 3 inches from either end must then be attached to serve as guides when the cage is removed and to keep the hoisting rope from untwisting when the locomotive is being lowered. It is important also to firmly belay the hoisting rope

*Should it develop that because of some local condition the airshaft cannot be used to join the men who have gone below it must be arranged to have three or four men take care of this part of the work from the start.

†If taking out the cage can be avoided by reducing the weight of the locomotive, it is best to do, as at many mines neither those in charge of the mine nor the men themselves like to have the cage removed, or the hoisting rope uncoupled.

to the guides or other permanent structure before uncoupling it from the cage, that when the weight of the cage is removed, the rope may not coil itself up in the shaft.

3—The hoisting rope may then be detached, and the cage taken out by removing from it the guide shoes, or taking out a section of the guides.

4—Then move the cage out of the way on rollers or greased rails, bring the locomotive up to the edge of the shaft, and fasten the hoisting rope to the locomotive coupler, etc., as outlined in item *3*, p. 1103.

5—After swinging the locomotive over the shaft, the guides must be fastened in position on the rope to prevent any turning when the apparatus is being lowered.

SLOPE MINE

If the locomotive is to be placed in service in a mine entered by a slope a thorough inspection should first be made of the slope, from top to bottom and the following noted:—

1—The height of the guide pulleys or rollers, in relation to the top of the track rails.

2—What is the minimum height from top of track rails to bottom of slope timbers?

3—What is the minimum clearance from track rails, right or left, to side of slope or slope timbers, etc.?

4—What is the height from the top of the track rails to the top of the highest pulley, roller, or other obstruction over which the locomotive must pass?

With this information, it will then be possible to decide regarding the following details:—

1—If the guide pulleys or rollers do not project more than two inches above the top of the track rails the locomotive can be run down the slope on its own wheels by attaching it to the hoisting rope after having tightened up the motor suspension and removed the gear cases, sandbox pipes, and such other details as are necessary to insure safe transit.

2—If the guide rollers or pulleys are more than two inches above the track rails and yet low enough to permit the bottom of the foot plates or bumpers to pass over them, the locomotive can be lowered down the slope on its own wheels by proceeding as in the first proposition, or if necessary the motors and such other details as will interfere may be removed.

When lowering a locomotive down a slope on its own wheels, two men should ride on it, one to control the brake, the other to operate the signal bell to the engine room to stop or start the engine as required.

3—When the guide rollers, pulleys, or other obstruction prevent lowering the locomotive down the slope on its own wheels, an endeavor should be made to obtain a car such as used on the slope for lowering timbers or special material. The locomotive can then be placed on this car and lowered down the slope very slowly, having securely blocked the locomotive front and back on the car. At least one man should ride on the car to handle the signal bell as required.

4—If the locomotive cannot be loaded on a car as a unit, because of limitations of height, etc., it must be taken to pieces and loaded in cars.

SETTING UP AND PLACING IN SERVICE

When the locomotive has been placed on the track near the bottom of the shaft or slope, the next step will depend on the amount of work to be done before all details are in place and all is

ready for hauling coal. If it is found that there are still several hours' work to be done and this is liable to interrupt operations in the mine, it will be better to get a mule and have the locomotive hauled to some location where the work can be finished undisturbed. If a mule cannot be obtained, five or six men can probably push the locomotive to the desired location.

All details required to place the locomotive in service should then be carefully gone over, including the following:—

1—Clean the locomotive thoroughly with new waste, and oil all bolts and bearings when re-setting the parts removed.

2—Open up the commutator housing lids and thoroughly clean the inside of the motors, the commutators, brushes, brush holders, etc.

See that each brush moves freely in its holder, and bears evenly on the commutator with a pressure of about five lbs. per sq. in. of brush end area. When all is clean and tight inside the motors, replace the commutator housing lids and set firmly in place.

3—Examine the oil boxes on the motors, making sure that they are clean, that they receive good oil, and that there is fresh, new waste in place.

4—Examine the pinions and gears, inspecting each tooth by pinching the locomotive forward until a complete turn of each gear has been made, and thoroughly oil and grease them before closing the gear cases.

5—Open up the controller, carefully inspect each finger and its contact, see that both are clean, and that each finger bears on its contact evenly and with the same pressure. In general practice each finger should bear on its contact with a pressure of from 10 to 12 lbs. After all adjustments have been made and all contacts are clean, rub a very small amount of vaseline over the face of each finger. Having inspected all connections, close the controller with both handles in the off position.

6—Next look over the resistance, making sure that each grid and frame or column is clean and dry and that all connections are in place and tight.

7—Examine the trolley with its movable contact and receptacle, and see that the trolley socket at the base is clean and oiled, and also the harp and trolley wheel. When the movable contact block is fitted on its receptacle, be sure that it sets tightly and evenly. The trolley pole cannot be cut nor the trolley spring adjusted until the maximum and minimum height of the trolley wire is determined; accordingly the mechanical parts may now be considered.

8—Release the journal boxes, and oil and inspect the journals; adjust the brake work, the motor suspension, the sand box rigging, headlights, etc., and have sand dried and ready to fill the sand boxes.

When a final inspection shows all is in place and all oiled and clean, put the trolley wheel on the wire and if light is obtained at the headlights try the locomotive over the run at very low speed, giving attention to the following:—

1—Before starting over the track with the locomotive it is well, as a matter of precaution to take the shine off the wheels that they may bear evenly and securely on the rails, to butt one of the bumpers against an immovable obstacle and, having sanded both rails under the wheels, spin them three or four times for about ten seconds each time.

2—When spinning the wheels note how the locomotive starts on the first series and the first multiple notch of the controller, and then accelerates, after having left word with those in charge of the generator at what voltage to run, so as to check the pressure on the trolley wire.

3—What is the minimum height of the trolley wire and the pressure of the trolley wheel at that point?

4—What is the maximum height of the trolley wire and the pressure at the trolley wheel at that point?

5—What is the clearance between the sides or ends of the locomotive and the timbers, door posts or ribs on straight road; also the clearance on the minimum curve?

6—What is the clearance between the top of the locomotive and the roof or cross timbers?

7—When at least one round trip has been made slowly, the trolley pole may be cut or adjusted to suit the trolley wire, endeavoring to secure as little variation in the pressure of the wheel on the wire as possible, and not less than about 15 lbs. at the maximum height, the pole making an angle of about 45 degrees with the top of the locomotive. As a simple test, if the trolley pole is 6 ft. long over all and set on a locomotive about 3 ft 4 in above the rail, it will readily reach a trolley wire at a maximum of about 7 ft 6 in above the rail

8—When the locomotive has been taken over the complete run, and all details as to clearance, etc., have been approved, it should be coupled to some cars and the details of the bumpers and coupling noted. If it pulls and pushes the cars satisfactorily, a trip with a few empty cars should be made and all curves taken, to see that the cars follow under all conditions when pushed and pulled.

9—Having decided that a trip may be handled satisfactorily throughout the run, by trying a few empty cars slowly, plan to haul the maximum load specified at about the third round trip. That is, if 30 cars are to represent the maximum load, haul from 15 to 20 the first trip, 20 to 25 the second, and 30 the third making an examination of all details between trips. If all proves well, extra trips may be made if desired by the management, or the official test may be made and approved in writing by them.

It is well to remember that care should be exercised before making any move, as the success of the undertaking and safety of the locomotive, as well as of those engaged to do the work depends on many items which in themselves call for but little effort, yet whose importance cannot be overlooked.

THE JOURNAL QUESTION BOX

Our readers are invited to use this department for obtaining information on electrical and mechanical subjects. The topics should be of general interest and of the kind that can be treated briefly. Each inquiry should be accompanied by a stamped return envelope.

Address all questions to The Journal Question Box, care of The Electric Journal, 200 Ninth Street, Pittsburgh, Pa.

796—Calibration of Large Capacity Ammeter, when no Shunt or Standard of Sufficient Capacity is Available—It is desired to calibrate a 5 000 ampere direct-current ammeter, but no shunt or standard ammeter of this capacity is at hand. Is there any method by which the millivolt drop across the meter shunt can be measured and the corerct values of current computed therefrom? B.L.

In order to check the ammeter it is necessary to either compare it directly with another ammeter of known accuracy or to determine the resistance of the meter and the millivolt drop across of the shunt. From this information the amperes can be calculated. The current will be equal to volts divided by resistance. The resistance of the shunt can doubtless be obtained by applying to the manufacturer of the meter, as it is usual for the makers of such instruments to keep a record of this information. You would, of course, have to supply serial or other designating number of the instrument. The millivolts drop of the meter shunt can be measured by means of a portable millivoltmeter. P.M.

797—Use of Lead Pipe for Transformer Cooling Coils—Would there be any objection to using lead pipe in transformers for the cooling coils in place of copper? The pressure would be two or three pounds and accordingly no danger of the pipe breaking and letting water into the oil. As lead pipe is much easier to bend and form and is generally easy to obtain, it could be used conveniently in many emergency cases. Of course, the heat conductivity of lead is low compared with that of copper. F.H.W.

Lead pipe is not substantial enough for such use. A puncture in the cooling coil might destroy the transformer and accordingly the material of which the coil is made should be strong and tough. Moreover, there might be impurities in the water which would attack lead pipe and destroy it. Accordingly, it should not be used for cooling coils except for extreme emergency conditions, and then should not be allowed to remain permanently in service. W.M.M.

798—Proper Spacing of Transmission Line Wires—How is the proper spacing between line wires of a high tension pole determined? J.O.F.

Proper spacing of transmission lines is determined by observation of current practice in that regard; thus, for very high-tension lines, spacing between wires may run to as high as 10 or 12 feet, and for lower operating voltages the spacing is reduced. There is no general rule so far as we are aware by which the proper spacing can invariably be determined; it is largely a matter of choice, the same transmission voltage being used with spacings varying sometimes as much as 50 percent. One of the items which has a considerable bearing upon the proper spacing is the size of objects which might accidentally interfere with the transmission lines, such as eagles, buzzards for the western lines and other animals, which may possibly make contact between adjacent wires. The usual spacing is so far above the actual striking distance of the voltage used that the striking distance can be said to have practically no effect upon spacing. The method of spacing hinges to a large extent upon the possibility of being able to work at one wire of a line with the other parts alive, or at one of two transmission lines on a given set of poles or towers when the other line is alive. In general, therefore, it can be said that there is no fixed rule for determining spacing, but recourse must be had to what other people

have done along the same line. The question of the spacing of conductors and reactance of the transmission circuits enters into the problem as a minor factor; the closer the wires, the less the reactance of the circuit, and hence the advantage of a minimum safe spacing so far as line drop is concerned, although the effect of this factor does not need serious consideration, except in the case of extremely low high voltage lines. As the spacing is decreased the electrostatic capacity of the circuits is correspondingly increased. Thus; in a high voltage, three-phase power cable, for example, the reactance is a minimum, while the capacity becomes appreciable. P.M.L.

799—Calibration of Service Meters with Portable Instruments—A split type current transformer and portable rotating standard watthour meter are to be used for testing watthour meters and current transformers combined, by putting a split transformer over the primary and using a rotating standard watthour meter on the secondary of the split transformer, having previously calibrated the split transformer and standard watthour meter to get good resultant curve. By adjusting the service meters accordingly this would appear to be a very easy method where current transformers are already installed. *a*—Would there be any error introduced in the split type current transformer by the primary wire not being in the center? *b*—What is the best method of testing current transformers for use with watthour meters? *c*—Can a polyphase graphic power-factor meter be tested with a single-phase portable power-factor meter? C.A.M.

a—In a split type current transformer the ratio curve is not very good, due to the usually low ampere-turns. For currents below 300 amperes this type of transformer is of no use unless calibrated together with its meter. Even then the readings will vary considerably due to different adjustments of the magnetic circuit. A more serious error when used with a wattmeter is that due to phase displacement which is inherently large in this type of transformer and which cannot be eliminated by calibration. This type of transformer is therefore unsuitable for wattmeter measurements and impossible for calibrating work in connection with wattmeters. Very little error would be introduced by the primary wire not passing through the center of the opening. *b*—Both the ratio error and phase displacement error should be determined. These are best obtained by a null method such as is used by the U. S. Bureau of Standards. This of course requires an expensive apparatus and is impossible for the ordinary user of current transformers to apply. The ratio may be checked by using standard instruments in the primary and secondary. The phase displacement that is typical of a given type of current transformer may be obtained from the manufacturer. *c*—A polyphase power-factor meter cannot be calibrated by comparison with a single-phase meter. W.E.W. AND H.E.T.

800—Pitting of Commutator—On a 550 volt, 130 ampere, 850 r.p.m. direct-current generator, the commutator is giving trouble. The insulation between segments is eating out and the bars at the outer end from the commutator have holes eaten between them one-quarter inch deep. When the machine is started and the voltage begins to rise, a ring of fire appears all around the end of the commutator, but after it comes up to voltage, the sparking stops and the machine runs well. Please tell me the cause of this and some way to fill in the places that are injured. The generator is pulling a street car load which at times runs to 75 percent overload, but for only a few seconds, however, at which time the machine runs well and without sparking. A.G.V.

It is generally considered that pitting or eating out of mica between commutator bars starts from some form of dirt getting on or into the mica segments. This dirt is more or less of a conductor and current carried by it, due to the voltage between bars, may sooner or later carbonize the mica so that it in turn becomes conducting. This process

of carbonizing or burning goes on until holes of considerable size are sometimes produced in the mica. Oil is a common vehicle for transmitting or holding the dirt and care should always be taken to see that no oil gets to the commutator by creepage, spraying or otherwise. A successful way of treating holes in the mica is to clean them out thoroughly, removing all burned and conducting material and then to fill them up with some form of high-grade cement. That used by dentists is very good. Plaster of Paris with sufficient shellac for a bond has also been used but is not so good as the dental cement. The filling material should be allowed to set thoroughly before the machine is used. The sparking at the end of the commutator is probably due to dirt of some kind. The end of the commutator should be thoroughly cleaned and then painted with a good insulation paint or varnish, this being renewed as often as necessary. The outer corner of the commutator should be slightly rounded (about 1/16 inch radius), and kept so as the commutator wears, as it is found that a sharp corner is much more apt to pit. All of the surface should be kept scrupulously clean. See article on "Care and Operation of Commutators" in the JOURNAL for May, 1912. W.A.D.

801—Installation of Squirrel Cage Induction Motors—Is it possible to install squirrel-cage, three-phase induction motors ranging in size from 10 to 200 hp with 440 volts so as to have same overload starting ability, power-factor and current consumption as is required by a wound rotor induction motor? If so, could the squirrel-cage motor and its starting equipment be made equally as reliable and durable as the other type? Please give comparative curves and explain the difference in influences on line and input load.

L.S.H.

General information on this question is given in the article on "Induction Motor Characteristics" in the JOURNAL for July, 1908, p. 366. In addition, the following specific information may be noted. There is a marked and essential difference between the starting characteristics of a squirrel-cage and a wound rotor induction motor. The main points in this difference are as follows: 1—The possible maximum starting torque. In a squirrel-cage motor, the maximum torque with which it can start from rest is limited by the design, and on average motors runs around 1.5 times full-load torque. This is true even when the pull-out torque of the motor may be as high as 3 to 3.5 times full-load torque. With a wound rotor motor it is always possible to develop a torque equivalent to the pull-out torque of the motor if the proper amount of resistance is inserted in the secondary circuit. 2—The power-factor when starting against full-load torque on an average squirrel-cage motor will be in the neighborhood of 55 to 60 percent, while the power-factor in starting against full-load torque with a wound rotor motor will be the same as the full-load power-factor, *i. e.*, probably from 85 to 90 percent. 3—Amount of starting current required: To start on full-load torque with an average squirrel-cage motor will require anywhere from 2.5 to 5 times full-load current from the line, whereas a wound rotor motor may be started against full-load torque with a current very little in excess of full-load current. From the foregoing, it will be noted that a wound rotor motor is more desirable from every point of view so far as starting conditions are concerned. Its only drawback is that the rotor winding is, of course, not so simple or rugged as in the case of the squirrel-cage motor. On circuits where the generator capacity is ample and where the size of the largest individual induction motor unit is not over one-third of that of the generator unit, it is often preferable to use squirrel-cage motors on account of their simplicity. If there is any question, however, of insufficient generator capacity or poor line voltage regulation, it is well to install wound rotor motors. Auto-starters for squirrel-cage motors may be made practically as durable as resistance starters for wound rotor motors. See Nos. 528, Feb., 1911, and 673, Dec., 1911. A.M.D.

802—Cutting Steel With Alternating-Current Electric Arc—In cutting steel, say, 0.5 to one inch in thickness by electric arc, what voltage and current are suitable on alternating-current circuit? What time is required for such thickness of steel?

We have no data on the cutting of sheet metal by alternating current and we do not know of anyone else who has. Direct current is used entirely for welding, and as the cutting on of metal is usually a secondary operation, such plants have also been used for this latter purpose. In order to apply an alternating-current arc for such work, it would, therefore, seem necessary to work out a solution, if such is possible, but we may mention that as the temperature would be rather lower with alternating than with direct-current, we do not think the former would be so effective. C.E.A.

803—Bad Regulation Due to Induction Motors—Will you please give me the necessary information on the following question: A 75 k.v.a. three-phase, 60 cycle, 600 volt generator furnishes light and power for a small plant. Three and five horsepower, three-phase, 550 volt induction motors are connected directly across the 600 volt mains for power. Three-600-575-550 volt primary to 220-110 volt secondary transformers step down the voltage for lighting purposes. When a five horsepower, high torque elevator motor is started up, the switchboard ammeter jumps up about fifteen amperes while the voltage indicated on the 600 volt voltmeter drops down about forty volts. This same thing happens to a less extent with a three horsepower conveyor motor. Will you kindly suggest a way to remedy this? Would a Tirrill regulator correct this fault and prevent the resulting dimming and flickering of the lamps?

The starting of the five hp motor means an increase of 15 amperes, or very nearly 15 k.v.a. in load on the generator. This is 20 percent of the rated capacity. At the low power-factor of the starting current the generator would have a regulation of 30 to 40 percent. With a change in load of 20 percent the change in voltage would be 6 to 8 percent of normal or, in this case, 36 to 48 volts. This checks fairly closely with the observed voltage drop, which shows the observed drop to be reasonable. A Tirrill regulator would help to a considerable extent, but would not act quickly enough to entirely eliminate the drop. This trouble is hardly avoidable when lights and elevator motors or other motors with large starting current, compared with the generator rating, are connected to the same generator. F.D.N.

804—Operation of Induction Motor—A 150 hp. water turbine working at 600 r.p.m. under a head of 150 ft. and provided with mechanical governor, is belted to a shaft requiring a constant speed of 100 r.p.m. Due to late increase of load, its speed falls off considerably, and it is proposed to belt an 80 hp., 400 r.p.m., constant speed induction motor, through suitable pulleys, to the 100 r.p.m. shaft, so as to be able to maintain the required speed. Please explain the behavior of the two machines under various conditions of load. C.I.

Up to its pull-out capacity the induction motor will carry all the load over and above what the water wheel will carry at 100 r.p.m. A.M.D.

805—Mounting of Ground Wire on Pole—Which is considered the better construction for mounting a ground wire on a pole; the use of staples or knobs? What serious objections are there of running a ground wire for lighting arresters in a small length of iron pipe used to protect the wire? E.V.R.

The purpose of the ground wire is, of course, to maintain ground or zero potential both on the pole and on the ground side of apparatus to which the wire may be connected, such as lightning arresters, or of an overhead grounded wire, as the case may be. It will therefore be seen that the use of knobs is unnecessary and is a disadvantage in keeping the pole at ground potential, especially when it is damp or wet due to rain. There is no the ground wire. F.R.S.

objection to the running of the ground wire in an iron pipe for protection of the wire, provided the very important precaution be observed of permanently soldering the pipe and wire together to get a durable low resistance connection between them. Otherwise the pipe would have a choking effect on the passage of current to ground via

806—Difficulty with Parallel Operation of Two Wound Secondary Induction Motors—Two 100 hp, 720 r.p.m. wound secondary induction motors are connected by chain drive to a pump. The motors are wired to run singly or in parallel, the connections being as in Fig. 806 (a). Our method of starting is to close first the three and four-pole switches between the controller and collector rings and between the controller and

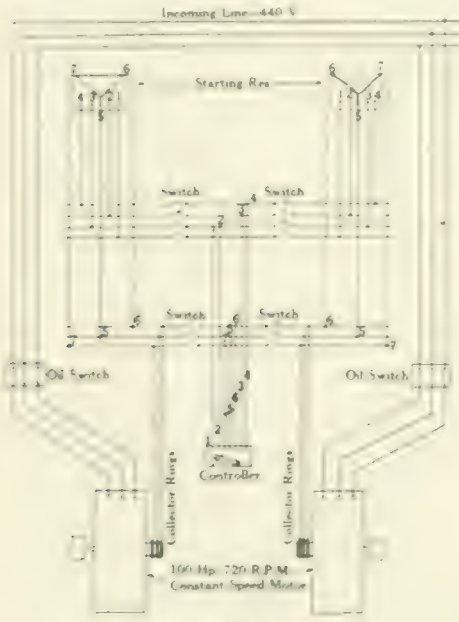


FIG. 806 (a)

starting resistance, respectively, to one motor, and then to close the oil switches connecting this motor to the 440 volt line. This, however, starts the motor with a jump and it reaches almost full speed before we have time to operate the controller; in fact, the latter does not seem to vary the speed. If there is any other way that we can connect the switch circuits to start slower will you please advise? L.B.

The trouble can probably be avoided by reversing the order of switching in starting the motors. Close both oil switches and after the motors have started and come to approximately the same speed, then close the four-pole switches and last, close the three-pole switches. The reason for the present trouble is that, with all knife switches closed, the rotors of the two motors are connected directly in parallel and it is probably impossible to close both of the oil switches at exactly the same time. The result is that the motor whose oil switch is closed first has its secondary winding short-circuited by the secondary winding of the other motor, and the motor at once comes up to full speed. After the motors are running, the controller should operate to slow them down, and if slow speed is desired for any continued length of time the three-pole switch should be opened; if the speed is not slow enough then, the controller should be notched back to the third position or to the off position. It will then be found that the motors will probably run at slower speeds without any trouble. See No. 750, June, 1912. H.L.B.

807—Overheating of Induction Motor Fields—A number of three-phase induction motors operating in a stone plant have given trouble due to over-heating of the fields. The windings are kept as clean as possible under the circumstances, and after cleaning are occasionally given a coat of shellac. The clearances are maintained by renewing bearings when required, and we have been careful to inspect the windings for loose connections. Please give causes and remedies for such over-heating. E.M.G.

Judging from the general information given in the question, the cause of the overheating would seem to be either overloading of the motor, or low supply voltage, and this would cause the motor to draw excessive current even if the load were normal. We would suggest that the voltage at the motor terminals be measured on all three phases, as well as the current in

each line under normal load conditions, and these readings compared with the name plate information. The remedies would then depend on what is thus found as well as on the way the trouble occurs, the frequency of recurrence, etc.

H.L.B.

808—Heat Equivalent of Electric Power—Every twenty-four hours we use 2,250 cubic feet of natural gas at 1 000 Btu. to maintain a temperature of 1 100 degrees F in a glass oven. How much electric power, i.e., how many kw-hrs. would be required to maintain the same temperature in this oven? Please give formula. Data regarding outside dimensions of oven, thickness of walls, character of walls, i.e., material used in their construction, number and size of doors or other openings, and details regarding their construction are given in the Fig. 808 (a). W.S.D.



FIG. 808 (a)

To estimate the exact quantity of heat required for such an oven as described requires data regarding the heat conducting qualities of ordinary materials, such as brick work, etc. From the information given in the question, we estimate that the radiation losses through the walls of the oven would amount to between 1 400 and 1 600 kw. This amount covers the approximate radiation losses only, and in the construction of new ovens, could probably be reduced by the use of a better quality of insulating material for the walls and by increasing the amount. The quantity of the glass which is being passed through the oven would also affect the amount of heat required, but we do not believe that it would be a very large percentage of that required to supply the radiation losses. We can not give a formula for the calculation of the electrical energy required, but the process for determining the amount of heat is as follows: The total amount of heat must equal the losses, plus the heat to do the work. The losses constitute those by conduction through the walls and radiation from the outer surfaces, and loss through ventilation and the resulting removal of the heated air. The loss by conduction depends upon the heat conductivity of the materials, together with the thickness of the wall and the exposed area. There are no set formulas for such calculation but the method of calculating the quantity of heat conducted through the walls is discussed in all good works on "Heat." F.P.

809—Effect of Omitting One Coil From Induction Motor Winding—What effect will it have on a squirrel cage rotor, three-phase induction motor to cut out one coil? Is it possible for getting satisfactory operation, and if so, what is the procedure for cutting out a coil? W.I.B.

The effect of cutting out one coil on an induction motor will be to make the phases unsymmetrical; the effect will be more or less pronounced according to the number of coils per pole per phase in the motor. If the number of coils per phase per pole is sufficiently large (at least 3 or 4) the cutting out of one coil will have no serious effect.

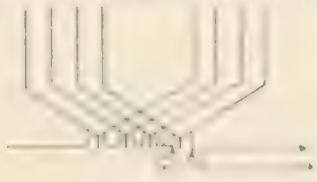


FIG. 809 (a)

The current per phase will be unbalanced and the performance somewhat poorer, but the motor in general will operate satisfactorily. If vice versa the coils per pole per phase are few, there may be noise, vibration and extra heating. To cut out one coil, open the connections as shown at *A.A*, in Fig. 809 (a). The ends of the dead coil *A.A*, should *not* be connected together and should preferrably be taped.

G.P.

810—Alternator Used as Generator or Motor—It is desired to operate a 120 brake horse-power, three-phase, 40 cycle, 220 volt, 400 r.p.m., alternator of the revolving field type having twelve poles and with a two horse-power, 50 volt exciter direct-connected to the shaft, as both a generator at normal frequency and as a 100 brake horse-power, 50 cycle, 220 volt motor without changing the rotor, by increase of speed in the latter case. How can this be accomplished? F.V.

If the 40 cycle, 400 r.p.m. generator is brought up to the necessary speed and synchronized with a 50 cycle supply circuit the machine will operate as a 50 cycle synchronous motor at 500 r.p.m., without any structural change being required. The change in operating frequency involves:—*1*—Increased speed which may not be mechanically safe; *2*—Decreased magnetic induction and decreased field ampere-turns, both of which tend to reduce the pull-out torque. This may be reduced below that required by the load to be carried. On the other hand the pull-out torque may be increased by increasing the excitation and operating the motor at a leading power-factor, if the armature winding will safely carry the increased current. Some suitable means for starting the motor must be provided. Very few generators will develop sufficient starting torque as synchronous motors to be self-starting.

F.D.N.

811—Telephone Transpositions—We wish to string two new telephone lines on the same poles which carry our 33 000 volt transmission line and ask you for information as to the best method or arrangement of transpositions to reduce as much as possible inductive noise. The transpositions in the transmission line are about 3⅓ miles apart. Should the telephone transpositions be arranged with special reference to those of the transmission line, and should the two telephone lines be transposed alike or should one be from left to right and the other from right to left? Our poles are 150 feet apart—in some places closer. Should the telephone transpositions be exactly the same distance apart? C.L.G.

It is desirable to make transpositions in the telephone lines comparatively close together. Every fourth or fifth pole would probably be close enough. The only reason for transposing the two lines with respect to each other would be the elimination of cross-talk. To do this transpositions of one line should be made half way between transpositions of the other line. In order to obtain the best results transpositions should be as evenly spaced as possible and the telephone wires should always be at an even distance from the transmission wires.

A.W.C.

812—Lightning Protection—*a*—To insure satisfactory protection against lightning, is it necessary to place arresters on the feeders coming out of the power house, and also on the same feeders as they enter the factory when the buildings are only about seventy-five feet apart? *b*—In a plant where there are a number of buildings and the feeders for both light and power run from one building to another is it necessary to have a lightning arrester at each building? *c*—To protect motors on cranes from lightning would it be good practice to place an arrester at the main trolley wheels, of course having the crane track well grounded and fasten the ground wire from the arrester to the bridge work of the crane? *d*—Is it advisable to use choke coils in connection with arresters on three-phase, 600 volt, 25 cycle power lines?

a—No. *b*—Should recommend arresters at both ends of any line over 300 feet long. *c*—Yes. *d*—It is not considered necessary since enough inductance to do any good would involve too much drop. We believe in general that for such local distribution the best practice is to use substantial steel construc-

tion and carry grounded conductors over the feeders. Very little lightning trouble will then be liable to occur. R.F.J.

813—Effect of Field on Power-Factor of Synchronous Motor—If Fig. 813 (*a*) represents a synchronous motor for the conditions of unity power-factor with a lagging current and also with a leading current; *a*—is it correct to make the assumption that since Ec_1 is less than Ec, that a weak field causes a lagging current; and since Ec_2 is greater than Ec, a strong field causes a leading current? *b*—Considering that I_1 represents a lagging current when extending to the right of I, why does not Ix, extend in the opposite direction from which it is shown, since it is a drop due to reactance and hence causing a lagging current? S.C.W.

a—The assumption made is measurably correct; it would represent the fact a little more correctly, however, to say that the generator and motor counter-generated e.m.f. must be such, in magnitude and phase relation, that the vectorial difference between them will be just sufficient to drive such a current through the impedance of the total circuit as will produce sufficient torque to carry the motor load. If the generator or line voltage be considered as constant, then the driving or actuating e.m.f. must be great enough to drive the current required for torque through the impedance of the motor armature. Since, over wide range, the torque is nearly proportional to the product of motor excitation (flux) and armature current in phase with the flux, the smaller the current the greater will be the flux. Or, the less the motor e.m.f., the greater the driving (or impedance) e.m.f., and hence the greater the current, which will be lagging with respect to the generator e.m.f. or leading with respect to the motor counter e.m.f., and so it will assist the motor excitation in producing sufficient flux to give the torque required for load. Similarly, with the motor counter-e.m.f. greater than that of the generator, the current is leading with respect to the generator, hence demagnetizing the motor field, by virtue of the phase displacement of the motor e.m.f. Were this not so, there would be the paradox of a generator delivering power against a superior (in phase) e.m.f. It will be found, that for actual power delivery to the motor, the component of its e.m.f. in phase with that of the generator, will always be less than the generator e.m.f. *b*—The difficulty with the *direction* of the reactance component is one of convention; one school represents the three e.m.f.'s in question as in Fig. 813 (b), the other as in Fig. 813 (c); the first school looks upon the generator e.m.f. as the *vectorial resultant* of the separate e.m.f.'s while the second regards the generator e.m.f. as the *vectorial equilibrant* of the constituent e.m.f.'s, or "drops." From the standpoint of physical significance, the second appears preferable, especially in view of the convention which makes power equal to the product of an e.m.f., a current and



FIG. 813 (a), (b), (c), (d)

In Fig. (a).
EA = Armature Voltage.
Ec = Counter—E.m.f.
I = Current in Phase.
I_1 = Lagging Current.
I_2 = Leading Current.

In Figs. (b), (c) and (d).
EG = Generator E.m.f.
EM = Motor Counter—E.m.f.
E1 = Driving E.m.f. or "Impedance Drop."
E = Line Voltage.
IR = "Resistance Drop" in Armature.
IX = "Reactance Drop" in Armature.

the cosine of the included angle; hence, generator power, or output, or positive power, always has an acute included angle, while motor power, or input, or negative output, must have the included angle obtuse, as will be evident from the original Fig. 813 (*a*), if the direction of motor e.m.f is reversed. Fig. 813 (*d*) is practically identical with the last combination mentioned in the question (i.e., that for leading power-factor with respect to the line) with the arrows reversed for all but line e.m.f.

N.S.

814—Pumping by Electric Motors—*a*—With 2 200 volt alternating current three-phase, 60 cycle power available, what would you consider the most efficient apparatus to pump water from wells of a depth and possible lift to the surface of from 80 to 120 feet with about 80 inches of water available from each well? *b*—What would be the best apparatus for pumping water against a head of 300 feet with units of about 250 hp each and load factors varying from 100 to 50 percent at different times of the year? A.L.S.

a—A vertical type of centrifugal pump is the logical one to use. It is assumed that the 80 in. referred to in the question means miner's inches, which would make the capacity about 895 gallons per minute. This would require a six inch vertical pump and it would be reasonable to expect an efficiency of 65 to 70 percent. It will be appreciated that with this capacity it would be impracticable to figure on a deep well type of pump. *b*—The capacity is not mentioned but the head is given as 300 feet and 250 hp is mentioned as the amount of power available. With the load factor varying from 100 to 50 percent at different times of the year, it would be desirable to use a triplex power pump. Assuming an efficiency of 75 percent, which is conservative, the capacity would be in the neighborhood of 2 500 gallons per minute. E.C.W.

815—Relative Merits of Prime Movers—*a*—On California oil (gravity from 16 to 18 Beaume and approximately 18 000 b.t.u.) with pumped water available in moderate quantities and labor for operating at about $80.00 per month what will be the relative merits of a first class steam turbine installation for delivering to the switchboard 2 200 volt, three-phase power in quantity of 880 kw, maximum, for 85 percent load factor, and an oil engine for the same service? *b*—What should be the depreciation of each if properly handled? A.L.S.

a—It is somewhat difficult to answer this question, as the price of oil is not given. We do not know of more than one case in which crude oil engines of the semi-Diesel type are using California oil, which, due to its asphaltic base, offers considerably more difficulties than the eastern oils. However, if the engine builders can guarantee satisfactory operation, it is probable that with oil costing more than 85c a barrel, or 2c a gallon, it would pay to install crude oil engines rather than a turbine plant. The question of additions to the plant in the future might have considerable bearing on this, and we would suggest that the question be referred to the commercial representatives of some engine manufacturer, or a consulting engineer familiar with the subject, who can figure this proposition in detail. It might not be out of place to mention that in figuring the cost of power from crude oil engines, it is always necessary to consider the difference in lubricating cost. In the turbine plant this is practically negligible, but in a crude oil plant, figures indicate it to be about 20 percent of the cost for fuel. *b*—The depreciation factor for the two plants complete, would probably be about the same. A close approximation would be 8 percent per annum for the turbine plant and 9 percent for the oil engine plant. H.A.R.

CONTRIBUTORS TO THE JOURNAL FOR 1912

Contributors for whom biographical sketches have already appeared in December issues of previous years are indicated by a (*).

D. H. Ackerson (Univ. of Cincinnati, '09), before graduation worked for one year for the Cincinnati Car Company, and for six months for the Cincinnati Traction Company; after graduation worked again for the latter for eleven months; in May, 1910, Mr. Ackerson entered the employ of the Electric Company as a special apprentice, and some months later took his present position in the railway equipment division of the railway and lighting sales department.

A. J. Airston (Birmingham Univ., England, '06; Carnegie Inst. of Tech., '12), apprentice with Messrs. Vickers Sons & Maxim, Aston, Eng., also served in works management and sales departments, 1906-10; commenced engineering apprenticeship course with the Electric Company, January, 1911; appointed head of factory lighting department, May, 1912.

C. E. Allen (Va. Polytech. Inst., '01); worked a short time for the South Western, Virginia & Tennessee Bell Telephone Company; entered testing department of General Electric Company, Lynn, Mass., same year, and engineering department, having charge of the experimental and development engineering on transformers until 1907; during that time, developed the so-called "distributed core transformer" now known as the "type H, form K," patents being in his name; then entered the commercial department on transformer sales, this work taking him over practically the entire United States; in 1909, entered employ of Electric Company in charge of the transformer sales division; in 1912 made assistant to manager, detail and supply department, his present position.

*C. B. Auel, director of standards, processes and materials, Electric Company.

*H. L. Beach, control division, industrial engineering department, Electric Company.

F. L. Bishop, Dean of School of Engineering, University of Pittsburgh.

D. S. Bowman (Purdue Univ., '05); with the Electric Company in the following positions since graduation: 1905-6, engineering apprenticeship course; 1907-10, power department; 1911 to date, commercial engineer, industrial and power department.

Q. A. Brackett (Harvard Univ., '06 and '07); with the Western Electric Company, New York City, for about one year in development laboratory; 1908 to 1910 in wireless telegraph and telephone work, first with Dr. Lee de Forest and later with Mr. F. Lowenstein, as laboratory engineer, factory superintendent, and sales manager, during which time the so-called Moscicki electric condenser and "quenched-spark" system, which is now fast displacing practically all other systems, were developed; became connected with Electric Company, fall of 1910, first on circuit breaker work and more recently on rectifiers and lightning arresters in the detail and supply engineering department, having recently taken charge of this work.

N. S. Braden, received training in a western college and was for five years attached to the Cleveland district office of the Electric Company as salesman and manager; for the past nine years, sales manager of the Canadian Westinghouse Company, Ltd., Hamilton, Ontario.

A. W. Brown (Municipal School of Tech., Manchester, England), whose father was in Great Britain for the Westinghouse interests, entered the works of the British Westinghouse Company in 1902 as an apprentice; entered electrical engineering department as assistant on resistance design, then controller design, including railway, automatic, and finally large liquid controllers and regulators, having charge of the latter; in 1907 was transferred to the general engineering department as assistant engineer on mining and rolling mill work; in 1908 started and carried through its official tests the first electric main shaft winding engine in Great Britain; early in 1910 was sent to South

Africa to take care of the installation of the first of the large electric winding engines installed there, returning to the works late in 1911 to resume previous duties.

D. S. Brown (Purdue Univ., '04), spent one year testing locomotives as assistant engineer on a dynamometer car operated by the International Correspondence School; one year as draftsman with the Latrobe Steel and Coupler Company, Chicago; one year chief draftsman with the Dayton Hydraulic Machinery Company, Dayton, Ohio; two years sales manager for the same company; one year in the Pittsburgh district sales office, Electric Company; one year in the industrial and power sales department's central station campaign work; one year directing travelers' system.

*Harold W. Brown, on staff of instructors of Sibley College, Cornell University; formerly, switchboard division, engineering department, Electric Company.

W. H. Bullock, with Electric Company since 1904, as engineering apprentice and since 1906 as salesman, Denver district office.

*D. E. Carpenter, industrial and power sales department, Electric Company.

H. F. Chadwick (Tufts College, '00), instructor in electrical engineering, Tufts College, one year; with Lorain Steel Company, Johnstown, Pa., 1901-2, as draftsman and checker; October, 1902, to date, with Electric Company at East Pittsburgh, holding position of draftsman, checker, assistant foreman of standard section, assistant chief draftsman and standard engineer. Mr. Chadwick has been identified with the American School of Correspondence, first as special instructor and writer, and since 1902, as a member of the advisory board. In 1903 he organized the Casino Technical Night School and was its first president; the degree of Master of Science was conferred by Tufts, June, 1911.

A. G. Chapin (Harvard Univ., '03), with Electric Company since graduation; apprentice course, 1903-5; four years in the direct-current sales correspondence department, and later in the railway and lighting sales department; for four years, salesman, railway and lighting division, Boston district office.

*C. E. Clewell, instructor, Sheffield Scientific School, Yale University; formerly, lighting division, detail and supply sales department, Electric Company.

A. B. Cole (Purdue Univ., '09); while at college took an apprenticeship course in interurban shop practice with the Grand Rapids, Grand Haven and Muskegon Railway, Fruitport, Mich.; with Electric Company since graduation; apprenticeship course, one and a half years; one year in railway equipment sales department; since 1911, department of publicity on railway publicity work.

*A. W. Copley, detail and supply engineering department, Electric Company.

P. L. Crittenden (Mass. Inst. of Tech.), one year with Armour & Company, Chicago; two years with American Telephone & Telegraph Company; two years with the Hudson River Telegraph Company as agent, trouble man and wire chief; nine years with The Westinghouse Air Brake Company as electrical inspector and electrical engineer.

J. L. Crouse, connected with Flint, Walling and Company, Kendallville, Ind., in erection department for five years; for three years with Monitor Manufacturing Company, Auburn, Ind., as general sales agent; with Electric Company since 1893 in the following capacities, testing and inspection department for five years; special railway work in New York City for seven years; special single-phase railway work two and a half years; on New Haven electrification for one and a half years; connected with railway engineering department for the past three and a half years.

*W. A. Dick, power division, engineering department, Electric Company.

*C. R. Dooley, president, Casino Technical Night School; secretary, educational committee, Electric Company.

*C. W. Drake, commercial engineer, industrial and power sales department, Electric Company.

*E. D. Dreyfus, West Penn Traction and Water Power Company.

*W. K. Dunlap, assistant to first vice-president, Electric Company.

GANO DUNN, as a telegraph operator in night service, supported himself while studying for a degree at the College of the City of New York, from which institution he graduated in 1889, and also while pursuing his electrical engineering studies for the degree of electrical engineer at Columbia University in 1891. Here he came in touch with Francis B. Crocker and Michael Pupin and other electrical pioneers, later following experimental work with the Crocker-Wheeler Company, where he rose from subordinate to responsible positions, becoming assistant chief engineer, then chief engineer, vice-president and director. His duties made him responsible for the design of both direct and alternating-current apparatus, and an experienced engineer in industrial and commercial applications of electric power. His first alma mater gave him the honorary degree of Master of Science in 1897. Under his direct general supervision such problems as the development of the three 4 000 kw gas engine driven alternators for the California Gas and Electric Corporation, a system for operating heavy-duty, two-high reversing roll trains for steel mills, the generator equipment of the drainage canal hydroelectric plant of the city of Chicago, and the design of various special machinery for the manufacture of electric apparatus, were solved. As an executive officer, Mr Dunn developed administrative qualities of the highest order, and frequently took personal charge, in the combined capacity of engineer and salesman, of negotiating for large contracts such as the preceding. He has been a manager of the A. I. E. E. (1897-02); a vice-president (1900 and 1905), and president (1911-12). He has also been a member of the committees on Constitutional Revision, High-Tension Transmission, Editing, and Building, as well as a representative of the Institute on the Board of Trustees of the United Engineering Society, of which he was vice-president during '11 and '12. He has also been on the International Electrotechnical Commission, and the Power Transmission Committee of the N. E. L. A. In November, 1911, Mr. Dunn was elected a director, and vice-president in charge of engineering and construction, of J. G. White and Company, since which time he has been concerned with hydroelectric developments, central lighting and power stations, electric and steam railways, and public utilities and service interests.

R. W. EATON (Mass. Inst. of Tech.), after graduation spent a year and a half at the East Pittsburgh works of the Electric Company, going from there to Boston on construction work; left the construction department after a year and a half and for the past five years has been connected with the sales department of the Boston district office, with headquarters at present at New Haven, Conn., specializing on steam railroad and street railway work.

A. D. FISHEL (Case School of Applied Science, '07), engineering apprenticeship course, Electric Company; at present in charge of transformer division, detail and supply sales department.

*S. A. FLETCHER, central station division, industrial and power sales department, Electric Company.

*H. H. GALLHER, in charge of experimental testing department, Electric Company.

C. B. GIBSON (Univ. of Minn., '05), on experimental research work, Electric Company, one and a half years; designing engineer, three years; industrial and power sales department, three years, in steel mill work covering electro-chemical, electro-metallurgical, electric furnace and electric welding applications.

JOHN F. GILCHRIST, with Commonwealth Edison Company, Chicago; president, National Electric Light Association, 1911-12.

L. F. GRANT (Case School of Applied Science, '04), entered the apprenticeship course of the Electric Company in July, 1905; in November, 1905, became connected with the Cleveland district office, since which time he has been engaged in sales work, specializing on electric motor applications for ore and coal handling machinery.

*G. W. HAMILTON, general engineer on mining work, engineering department, Electric Company.

F. C. HANKER (Purdue Univ., '02), has been connected with the Electric

Company since graduation, for eight years in the engineering department and for the last three years in charge of engineering work on United States government contracts.

P. N. HARRISON received his electrical training at the Carnegie Institute of Technology, and at the works of the Electric Company; now connected with the industrial and power sales department of the Seattle district office, where his work has been largely on the application of motors in the various industries, and on central station work.

*R. E. HELLMUND, engineer-in-charge of direct and alternating-current railway motor design, engineering department, Electric Company.

E. W. HENDERSON (School of Mining, Queen's Univ., Kingston, Ont., '05) spent two and one-half years with the Electric Company, first as engineering apprentice and later in the railway engineering department; appointed lecturer in electrical engineering, School of Mining, Queen's University, 1907; at present, assistant professor in electrical engineering, School of Mining.

*E. M. HERR, president, Electric Company.

D. C. HERSHBERGER (Casino Technical Night School, '06; also one year post-graduate work), switchboard inspector, 1906-9; switchboard draftsman, 1909-11; general engineering department, 1911-12.

*J. M. Hipple, engineer-in-charge, industrial engineering department, Electric Company.

*FRANCIS HODGKINSON, engineer, turbine department, The Westinghouse Machine Company .

G. H. F. HOLY (West Virginia Univ., '01), with The Westinghouse Machine Company, 1899, as machinist's helper; Electric Company, 1899-01, winding electric apparatus, and 1901-2, drafting department; in drafting department of Riter-Conley Manufactruing Company, 1902-5; Electric Company, drafting department, 1905-10, railway engineering department, 1910 to date; at present in charge of locomotive design.

*L. FREDERIC HOWARD, chief engineer, Union Switch & Signal Company, Swissvale, Pa.

W. P. HURLEY (Purdue Univ., '06), after graduation was with the Philadelphia Electric Company; two years in the testing and engineering department of the General Electric Company; one year as instructor in the electrical department of the Carnegie Technical Schools; at present in the detail and supply sales department of the Electric Company.

H. A. HUSSEY (Univ. of California, '09) entered apprenticeship course of the Electric Company, 1909, and during the following two years was on work connected with the Pennsylvania Railway electrification at New York City for a period of about six months; during 1911-12 was connected with the Westinghouse Lamp Company at Bloomfield, N. J.; August, 1912, entered the railway and lighting department of the Electric Company, now being located at the San Francisco district office.

*R. P. JACKSON, engineer on high-tension insulation, research engineering department, Electric Company.

*H. D. JAMES, assistant to manager of engineering, in charge of general engineering department, Electric Company.

W. J. KYLE, in the early 90's left school and was in the employ of the People's Traction Company of Philadelphia, for a short time on outside construction; then entered the employ of the Philadelphia Edison Company, reaching the position of chief inspector; with the Telephone Companies testing and inspecting underground cables at the cable factory prior to shipment; returned to central station work in 1903, building the plant of the Baltimore Electric Power Company, Baltimore, Md., and also the Delmarnia Construction Company's plant at Wilmington, Del., which is owned and operated by the same interests; during this development work he became interested in the question of power rates and the securing of power business, and gained considerable commercial experience during this period, securing a 1 000 horse-power central station service contract with the Jackson & Sharp plant at Wilmington, Del., at a time when 100 horse-power on central station service was considered a large contract; later became connected with the sales organization of the Electric Company at Chicago, in the capacity of central station power engineer; at

present with H. M. Byllesby & Company in connection with the Minneapolis General Electric Company, Minneapolis, Minn.

*M. B. LAMBERT, in charge of equipment division, railway and lighting sales department, Electric Company.

*B. G. LAMME, chief engineer, Electric Company; chairman, publication committee, THE ELECTRIC JOURNAL.

A. C. LANIER, (Univ. of Tennessee; also degree of M.E.E., graduate school of applied science); testing department, General Electric Company; instructor in mechanical engineering, University of Tennessee; assistant professor of electrical engineering, University of Cincinnati; designing engineer, Electric Company, and at present, section engineer on direct-current design, industrial engineering department.

*CHARLES A. LAUFFER, M.D., medical director, relief department, Electric Company.

*C. S. LAWSON, section engineer on design of large capacity indoor and outdoor types of self-cooled transformers, transformer engineering department, Electric Company.

*E. E. LEHR, section engineer on design of feeder voltage regulators, industrial engineering department, Electric Company.

*BERNARD LESTER, in charge of small motor division, industrial and power sales department, Electric Company.

*P. M. LINCOLN, general engineer, Electric Company; member, publication committee, THE ELECTRIC JOURNAL.

GEO. M. LITTLE, (Case School Applied Science, '93), worked for three months after graduation for J. H. Cremer, Cleveland, Ohio, on ore analysis; with National Carbon Company for eleven years on chemical and engineering work; 1905 to date, Electric Company on arc lamp and electrode development work.

*H. E. LONGWELL, consulting engineer, The Westinghouse Machine Company.

HARRY N. LUCAS, (Ohio State Univ., '06), entered the apprenticeship course of the Electric Company, July, 1906; erecting engineer on metallic flame arc lamps, 1908-9; salesman Philadelphia district office, 1909 to date.

*O. S. LYFORD, JR., consulting engineer, Westinghouse Church Kerr & Company.

* W. M. MCCONAHEY, engineer in charge, transformer engineering department, Electric Company.

*HAROLD MCCREADY, electrical engineer, Union Switch & Signal Company.

C. H. MCCULLOUGH, entered the apprenticeship course of the Electric Company in January, 1899, and after being connected with the testing department took up work in the correspondence, engineering and sales departments; for the past three years, Pittsburgh district sales office.

JOSEPH MCKINLEY, (Pennsylvania State College, '00), was with the Electric Company from August, 1911, to September, 1903, in apprenticeship work in the shops and testing departments; with the Allegheny County Light Company, 1903 to the present time, selling electric power, and in industrial engineering work; elected president of the County Light Section, N. E. L. A., for the year, March, 1912, to March, 1913.

NORMAN MACBETH, formerly illuminating engineer for the Welsbach Company, and later for the Westinghouse Lamp Company; consulting illuminating engineer, New York and Philadelphia; since Nov. 1st, 1912, editor, *Lighting Journal,* New York City.

J. N. MAHONEY, with Boston & Revere Electric Lighting & Railway Company, 1889; Electric Storage Supply Company, Boston, 1890; subsequently with the Electric Illuminating & Power Co., Long Island City, with the New York & Queen's County Co., the New York Brake Co., the American Electric Brake Co., and The Westinghouse Air Brake Co., for a total period covering fifteen years; for the last six and a half years with the Electric Company, including one year as engineer on railway control and equipment design, one year on mining locomotive and electric locomotive design, two years as mechanical engineer on railway and industrial controllers; for the past two years engineer on circuit breaker and switching apparatus in the switchboard engineering department; while with the Electric Company also acting in a consulting capacity for The Westinghouse Air

Brake Company on electro-magnetic and electro-pneumatic brake apparatus.

H. D. MURDOCK, after graduation from Cooperstown Academy, took up special engineering work at Cornell University; 1891-2, power house and car equipment work with Los Angeles Electric Railway Company; apprenticeship course, Electric Company, 1892; after three months shop work, entered erection department and went to Brooklyn to superintend the installation of power house and cars for the Brooklyn City Railway Company; 1894-8, car equipment and power house work in Philadelphia, St. Louis and Baltimore; district engineer, Pittsburgh office, Electric Company, 1898-1906; superintendent of Fifty-second Street shop of Brooklyn Rapid Transit Company, 1906-7; superintendent of the Indianapolis and Lousville Traction Company for four years, this being the pioneer 1 200 volt, direct-current road in this country; in September, 1911, accepted position with the Electric Company to superintend the 1 500 volt direct-current installation of the Piedmont & Northern Lines in North and South Carolina.

S. S. NEU, (Columbia Univ., '01), engineering department Crocker-Wheeler Commpany, 1901-3; in electrical construction business in New York City, 1901-6; Crocker-Wheeler Company 1906-9, since which time he has been connected with the publicity department of the Electric Company.

*F. D. NEWBURY, engineer-in-charge, power engineering department, Electric Company; associate editor, THE ELECTRIC JOURNAL.

E. M. OLIN, (Purdue Univ., '94), with Electric Company since August, 1894, as student on apprenticeship course; testing department, chief of testing department; engineering department, designing induction motors, alternators and rotary converters; road engineer for four years on expert trouble work: at present, assistant superintendent, head of testing department.

G. D. OTTAWAY, after receiving technical education at Brighton and Lincoln, England, Technical Schools, served apprenticeship with Ruston-Proctor & Company, general engineers, Lincoln, Eng., from 1895 to 1901; mechanical engineer with British Westinghouse Company 1901-3, on foundation and structural work; entered service of the Electric Company in 1903 as draftsman on equipment of plant, and layout work; later transferred to work on purchasing and disposal of machinery.

T. J. PACE, has been connected with the Electric Company for the past twelve years, being engaged in lamp sales work; at present in charge of the lighting division of the detail and supply sales department.

C. B. PADON, (James Millikin Univ., '07), while serving apprenticeship as machinist and tool maker, 1899-03, took preparatory engineering course with International Correspondence Schools; instructor in machine shop practice, James Millikin University, Decatur, Ill., 1905-6; with Electric Company since 1906, on apprenticeship course, 1907-8; on installation of electrical apparatus, Illinois Steel Company's coke plant, 1908-9; main and sub-station installation work with Sanitary District of Chicago, 1909; the last three years detail and supply sales department, Chicago district office, specializing on switchboard sales engineering.

*W. H. PATTERSON, in charge of resale division, industrial and power sales department, Electric Company.

W. O. PEALE, (Polytech. Inst., '04,' post graduate, '05), apprenticeship course, General Electric Company, in testing and engineering departments 1905-7; assistant to chief engineer, Simplex Electric Heating Company, Cambridge, Mass., 1907-8; since 1908, in the industrial engineering, and detail and supply engineering departments, and at present in the detail and supply sales department of the Electric Company, on electric heating apparatus.

*T. S. PERKINS, engineer in charge detail and supply engineering department, Electric Company.

F. R. PHILLIPS, subsequent to private instruction in mechanics, dynamics, statics, electro-chemistry, metallurgy and higher mathematics, for the past eighteen years has been identified with street railway engineering work, as follows: from 1894 to 1903 with the Cleveland City Railway Company in various departments, including the transportation, power, mechanical and engineering

departments, being appointed master mechanic of the shops in 1903; April 1904 to June 1906 with the Cincinnati, Newport & Covington Light & Traction Company, with the Michigan United Railways Company, as chief engineer; with the Ohio Brass Company as engineer in charge of railway developments; July, 1908, to December, 1909, master mechanic for receivers of the Cleveland Railway Company, Cleveland, Ohio; 1909 to date, superintendent of equipment, Pittsburgh Railways Company.

*A. G. Popcke, commercial engineer, industrial and power sales department, Electric Company.

Harlan A. Pratt, (Stevens Inst. of Tech., '04), while pursuing his studies at Stevens Institute spent the summer vacation in the employ of the Public Service Corporation of New Jersey, in their various departments; then went to the Niles-Bement-Pond Company in their crane works in Philadelphia, and later in their Pratt & Whitney shops, Hartford, Conn.; since December, 1904, with the Electric Company, as sales engineer in the New York district office, at present in charge of the industrial and power division of this office.

Harry C. Pratt, (Norwich Uni., Northfield, Vt., '07), assistant on engineering corps, Missouri Pacific Railroad, 1907; with the Vermont Marble Company from February, 1908, to date, being engaged during 1908-10 in engineering and construction work; during 1910-11 as superintendent of cutting of building marble, and from 1911 to date as assistant superintendent, finishing department.

D. C. Pultney, after completing a four-year apprenticeship course as a mining engineer with the Summerlee Iron and Coal Company, moved to the city of Glasgow, where he entered the service of Wm. Dixon, Limited, Iron Manufacturers, taking up blast furnace and rolling mill construction; later, for some years with the Steel Company of Scotland; after coming to America, was employed for about seventeen years with the Carnegie Steel Company; in 1908 entered the service of the Electric Company, his present capacity being safety appliance engineer, manager of works department.

*K. C. Randall, engineer in charge switchboard division, engineering department, Electric Company.

*E. G. Reid, engineer on design of distributing transformers, transformer division, engineering department, Electric Company.

*A. E. Rickards, general manager, Industrial Engineering Company, Pittsburgh, Pa.

*Charles R. Riker, assistant editor, The Electric Journal.

H. A. Rogers, has been connected with the Electric Company for the past seventeen years in various capacities, more recently being chief clerk in charge of the time and pay rolls division, and for the past three years superintendent of the relief department.

G. W. Roosa, (Union College), for approximately four years was connected with the General Electric Company at their various works at Schenectady, Lynn, and Pittsfield, where he worked on flame carbon arc lamps in the engineering department. Previous to this, he was connected with the service department of the Electric Company at Buffalo, with the Niagara, Lockport & Ontario Power Company on 60 000 volt transformer sub-station work, and with the International Railway Company of Buffalo. In 1910 he returned to Union College and took a post-graduate course under the personal direction of Dr. Steinmetz, head of the electrical engineering department, receiving the degree of Master of Electrical Engineering, June, 1910. Since February, 1912, he has been connected with the detail and supply sales department of the Electric Company as commercial engineer.

G. B. Rosenblatt, (Columbia Univ., '02), worked for the Otis Elevator Company for a short while on research work covering the application of alternating-current motors to elevator work, and about six months later, entered the apprentice course at the Electric Company; in 1903 entered the transformer engineering department; made a tour of the West investigating high-tension transformer troubles, and upon his

return to Pittsburgh, took charge of the designing of small distributing transformers and various special transformers, in the engineering department; took up some personal work in 1905, and returned in 1906 to take charge of the Butte office, where he remained until early in 1912, since which time he has been following mining work in the Western district offices of the Electric Company.

E. B. Rowe, (Mass. Inst. of Tech., '06), since graduation has served one year as instructor in the electrical standardizing and testing laboratory at M. I. T.; six months as assistant to the superintendent of lines and bonding, Old Colony (Mass.) Street Railway; one year in the laboratory of the Boston Edison Co.; and since that date with the Holophane Co., in publicity and general engineering work, and assistant chief engineer for the past two years. Mr. Rowe has contributed much original data to the cause of better illumination during the past several years.

H. H. Rudd, (Trinity College, '01; Rensselaer Polytech. Inst., '03-4), with Electric Company, 1904 to date; at present in charge of large power transformer division, railway and lighting sales department.

William Schaake, (Univ. of Mich., '95), was for four years after graduation engaged in the design of electric traveling cranes; with the General Electric Company for three and a half years on design of railway equipment; engineer on railway equipment with the British Westinghouse Company for one and a half years; railway project work Electric Company, one and a half years; during the past three and a half years, engineer on line material and trolleys.

*H. M. Scheibe, engineer in charge of electric fan motor design, detail and supply department, Electric Company.

T. M. Schoepf, (Rensselaer Polytech. Inst., '98; Johns Hopkins Univ., '99), before attending college was engaged for several years in the construction and operation of electric railways; entered the employ of the Electric Company, November, 1899, with the construction and engineering departments until September, 1901, when he was transferred to the British Westinghouse Company; while in England was engaged on electric railway and general engineering work; in May, 1907, he returned to the Electric Company, and has since been connected with the engineering department, at present being in the general engineering division.

*Geo. P. Scholl, consulting engineer, Westinghouse Lamp Company, Bloomfield, N. J.

L. G. Schumacher, (Univ. of Illinois, '07), with the Electric Company since graduation; for the past three and a half years has been engaged in commercial engineering in the industrial and power sales department at East Pittsburgh, on mining and industrial locomotives.

*Chas. F. Scott, professor of electrical engineering, Sheffield Scientific School, Yale University; consulting engineer, Electric Company; associate editor, The Electric Journal.

*H. D. Shute, acting vice-president, Electric Company.

J. J. Sinclair, (Stevens Inst., '01), entered the apprenticeship course of the Electric Company in 1901, and was transferred to the railway engineering department the latter part of the same year; in February, 1904, went to New York on construction, sales and engineering work in connection with the railway and lighting division of the New York office, where he is now located.

*C. E. Skinner, engineer-in-charge, research engineering department, Electric Company; associate editor, The Electric Journal.

E. M. Smith, Cleveland district office, Electric Company.

E. W. P. Smith, (Colorado College, '08), assistant to chief engineer, West Hayden Townsite Co., Denver, Col., 1908; operator, Pike's Peak Hydro-electric Company, Manitou, Colo., 1909; apprentice, Electric Company, first in shop and then in the railway engineering department, 1909; assistant designer, single-phase motors, and mechanical parts of locomotives, 1909-12; recently became associated with Geo. S. Rider & Company, consulting engineers, Cleveland, Ohio, 1912.

J. E. Snyder, after serving an apprenticeship as machinist at the

Pittsburgh Locomotive Works, and holding various subsequent positions, was employed by The Westinghouse Machine Company, and has been connected with this company in the construction, erection and testing of steam turbines for the past fifteen years; at present has entire charge of all shop work in connection with the manufacturing and testing of steam turbines at the East Pittsburgh works of the company.

*E. R. SPENCER, assistant editor, THE ELECTRIC JOURNAL.

*NICHOLAS STAHL, commercial engineer in charge of general contract division, railway and lighting sales department, Electric Company.

CHARLES PROTEUS STEINMETZ, was educated at the Gymnasium (high school) and then University Breslau, where he studied mathematics and astronomy, then physics and chemistry, and finally for a short time medicine and national economy. Involved in the social democratic agitation against the government, he escaped to Switzerland in 1888, and there studied mechanical engineering at the Polytechnische Zurich. Upon coming to America in 1889 he found a position with the Osterheld & Eickemeyer Manufacturing Company, first as draftsman, then as electrical engineer and designer, and finally on research work in charge of the Eickemeyer laboratory. With the absorption of the Eickemeyer interests by the General Electric Company, Dr. Steinmetz joined the latter organization, and was attached to Mr. H. F. Parshall's calculating department in Lynn, Mass. With the transfer of the Company's headquarters to Schenectady, in 1894, Dr. Steinmetz organized and took charge of the calculation and design of the Company's apparatus, and of the research and development work. Since 1902 he has been professor of electrical engineering at Union University, at the same time retaining his connection with the General Electric Company as chief consulting engineer, and about three years ago again entered into closer relation with this Company by organizing a consulting engineering department under his charge. Dr. Steinmetz is the author of many important publications and articles on the fundamentals of electrical engineering and applied physics and mathematics, most of the papers on electrical subjects being published in the Transactions of the A. I. E. E. He has also published a number of well known books, including a popular work on "Astronomy and Meteorology," in the German language, first edition 1880. His more recent books are on theory and practice of applied electrical engineering. In 1902 Dr. Steinmetz received the honorary A.M. degree from Harvard University, and in 1903 the honorary Ph.D. degree from Union University. Dr. Steinmetz is a past president of the A. I. E. E., honorary member of the N. E. L. A., fellow of the Am. Assoc. for the Advancement of Science, member of the American Mathematical Society, the Quaternion Society, the A. S. M. E., Ethnological Society, Illuminating Engineering Society, and the Physical Society.

*C. E. STEPHENS, general engineer of lighting equipment and illumination, general engineering department, Electric Company.

LEWIS BUCKLEY STILLWELL, entered Wesleyan University, Middletown, Conn., September, 1882, remaining only until the end of Sophomore year, after which he entered Lehigh University and completed the electrical engineering course in 1885. In the autumn of that year he returned to take a special course in mechanical engineering, but becoming seriously ill left the college, and upon his recovery, accepted appointment as assistant electrician of the Electric Company at Pittsburgh. Here he became associated with C. B. Shallenberger, William Stanley and others, who, at the time, were doing pioneer alternating-current work, and the next four years were devoted to developments in this field. In 1890 he became chief electrical engineer of the Company, and in 1895 his duties were further extended to include those of assistant manager. From 1892 Mr. Stillwell gave much of his time to the development of the plans for the utilization of the power at Niagara Falls, and, following the award of the initial contract for electric generating apparatus to the Elec-

tric Company which he represented, assumed immediate charge of the construction and installation of the electric plant. In March, 1897, he severed his connection with the company and was appointed electrical director of the Niagara Falls Power Company and the Cataract Construction Company. His arrangements with these companies were not exclusive, and while extending and operating the plant at Niagara he acted as consulting engineer for various other power and railway projects, among others the equipment of the elevated lines of the Manhattan Railway Company in New York. Having completed the installation of the first 50 000 horse-power plant at Niagara in September, 1900, he resigned his position with the Niagara companies and removed to New York. He was then appointed electrical director of the Rapid Transit Subway Construction Company, thus having in charge at that time the electrical equipment of both elevated railways and the subway system of New York City. After completing the equipment of the elevated lines and the subway, which in the meantime had been extended to Brooklyn, he became consulting engineer to the Hudson Companies, in charge of electric equipment of the four tunnels constructed between Manhattan Island and New Jersey. He was a member of the commission formed by the Erie Railroad Company, in 1905, to report upon the electrification of the suburban zone of the Erie lines in the vicinity of New York, and is consulting engineer to the United Railways & Electric Company of Baltimore, the Lehigh Navigation Electric Company and other important corporations. Mr. Stillwell has received the honorary degrees of M.S. from Lehigh University and the Sc.D. degree from Wesleyan University. He is a past president of the A. I. E. E., member of the American Society of Civil Engineers, the British I. E. E., the Am. Philosophical Soc., the British Society of Arts, the Am. Assoc. for the Advancement of Science. In the electrical field Mr. Stillwell has taken out numerous patents, the more important of these relating to the regulation of potential in distribution systems, the original broad patents covering conductive regulation having been issued to him in 1888, the localization of interruptions of service in systems of distribution by means of time limit circuit breakers, and the control of systems of distribution by means of pilot switchboards.

*W. R. Stinemetz, commercial engineer, railway and lighting sales department, Electric Company.

*N. W. Storer, general railway engineer, engineering departemnt, Electric Company.

*R. W. Stovel, mechanical engineer, Westinghouse, Church, Kerr & Company.

A. F. Strouse, with Industrial engineering Company, Pittsburgh, Pa.

*Alexander Taylor, manager of works, Electric Company.

W. E. Thau (Univ. of Cincinnati, '11), joined the apprentice course of the Electric Company after graduation and is now located in the industrial motor application section of the general engineering department.

*W. H. Thompson, engineer in charge of electric ozonizer apparatus, detail and supply engineering department, Electric Company.

J. M. Tomb has been connected with the Electric Company since 1904; on the apprenticeship course until June, 1907, when he was sent to New York on the New Haven electrification; Oct., 1908, Garden City, L. I., to conduct tests on Pennsylvania locomotives; returned to East Pittsburgh, Dec., 1908, and was in the industrial and power sales department until Feb., 1909; since that date, sales department, Boston district office.

*M. C. Turpin, in charge of editorial division, department of publicity, Electric Company.

*J. E. Webster, mechanical engineer on railway locomotive equipment, general engineering department, Electric Company.

*J. W. Welsh, electrical engineer, Pittsburgh Railways Company.

*W. B. Wilkinson, with Mahoning & Shenango Railway & Light Company, Youngstown, Ohio; formerly connected with the Pittsburgh district office of the Electric Company.

C. E. WILSON (Carnegie Inst. Tech., '09), has been connected with the Electric Company since graduating; at present in the industrial engineering department, in development work on automobile starting motors and lighting generators.

E. M. WISE, after serving an apprenticeship with Electric Company, was with British Westinghouse Company at Manchester, Eng., for three years, and for the past six years has been with the Pittsburgh district office as salesman in the resale division.

W. B. WREAKS (Stevens Inst. Tech., '89); 1889-92, with United States Electric Light Company, Newark, N. J.; 1892-95, engineering department, Electric Company; 1895-00, salesman New York district office; 1903-09, salesman Detroit district office; 1909-11, manager Detroit office; January, 1912, to date, partnership, Wreaks & Noyes, consulting engineers, Detroit, Mich.

*F. E. WYNNE, engineer in charge of project section, general engineering department, Electric Company.

J. L. McK. YARDLEY (Univ. Penna., '04), during 1904-6 was connected with the Schenectady shops of the General Electric Company, as tester; 1905, 6 and 7, assistant to the superintendent of the Ontario Power Company at Niagara Falls; during 1907-10 engineer on trouble and testing work for the Buffalo office of the Electric Company; July, 1910, to date designing engineer, power engineering department, Electric Company.

CONTRIBUTORS TO THE JOURNAL QUESTION BOX—1912

The following list of contributors who have furnished answers to inquiries published in THE JOURNAL Question Box during the present year, will indicate in a general way from what responsible and varied sources this information is obtained. This department of the JOURNAL is at the disposal of its subscribers as a means of obtaining advice on electrical and mechanical topics. Except where specifically stated, the contributors are associated with the Electric Company.

C. B. AUEL, director, standards processes and materials.

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A. P. BENDER, railway and lighting sales department.

H. W. BROWN, switchboard division, engineering department.

A. BRUNT, industrial division, engineering department.

G. L. CHRISTMAN, switchboard division, engineering edpartment.

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A. W. COPLEY, detail and supply division, engineering department.

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S. W. DUDLEY, assistant chief engineer, The Westinghouse Air Brake Company.

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R. P. Jackson, research division, engineering department.

H. D. James, assistant to manager of engineering, in charge of general division, engineering department.

A. T. Kasley, assistant to chief engineer, The Westinghouse Machine Co.

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B. G. Lamme, chief engineer.

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E. E. Lehr, industrial division, engineering department.

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G. J. Schmidt, industrial division, engineering department.

C. E. Skinner, engineer in charge, research division, engineering department.

H. C. Specht, industrial division, engineering department.

E. R. Spencer, The Electric Journal.

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C. W. Starker, industrial division, engineering department.

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H. R. Stuart, industrial division, engineering department.

W. Sykes, general division, engineering department.

R. W. Tassie, general division, engineering department.

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F. Thornton, detail and supply division, engineering department.

A. A. Tirrill, general engineer, detail and supply division, engineering department.

H. C. Walter, industrial division, engineering department.

E. C. Wayne, the Goulds Manufacturing Company, Seneca Falls, N. Y.

W. S. Woodward, transformer division, engineering department.

J. L. McK. Yardley, power division, engineering department.

PERSONALS

Mr. Chas. A. Hobein has resigned as perintendent of power stations for the nited Railways Co., St. Louis, effective ov. 1st, to accept a position as elec- ical and mechanical engineering ad- sor and inspector for the bond house John Nickerson, Jr., St. Louis.

Mr. J. P. Moore has recently become sociated with the general engineering partment of the Westinghouse Elec- ic & Mfg. Company, having resigned om his recent position with the Wyan- tte Construction Company, Kansas ty, Mo. Mr. Moore has had consider- le experience with a number of com- nies during the last several years in ctric power transmission and central tion work.

Mr. C. A. Gross, who has been with e Boston office of the Westinghouse lectric & Mfg. Company, specializing textile work, has been transferred to e Philadelphia office.

Mr. J. P. Alexander has been trans- rred from the engineering department the Westinghouse Electric & Mfg. mpany to the New Haven sales office.

Mr. E. W. P. Smith, until recently nnected with the railway engineering partment of the Westinghouse Elec- ic & Mfg. Company, has taken a posi- n with George S. Rider & Co., con- ructing engineers, Cleveland, Ohio. r. Smith's name is familiar to JOUR- AL readers in connection with the ticles on "Single-phase Commutator otors" appearing in various issues of e present year.

Mr. A. R. Fairchild, assistant elec- cal engineer of the Washington ater Power Company, has resigned to ke up similar work with the Tennes- e Natural Development Company, eenville, Tenn.

The following men who have recently ished the engineering apprentice urse of the Electric Company at East ttsburgh have been transferred to les offices as given below: Mr. A. L. ber, I. & P. dept., Salt Lake City of- e; Mr. C. W. Johnston, Detroit office; r. C .B. Cushing, Philadelphia office; r. H. W. Brooks, Denver office; Mr. . C. Vincent, D. & S. dept., Philadel- ia office.

Mr. Leonard Work, until recently of the Philadelphia office of the service department of the Westinghouse Electric & Mfg. Company, is now foreman in the engineering and construction department of the Isthmian Canal Commission, with headquarters for the present at Pedro Miguel, C. Z.

OBITUARY.

JOSEPH LECONTE DAVIS

Whereas, An all-wise Providence has removed from our midst, our friend and fellow-worker, Joseph Leconte Davis;

Be It Resolved, That it is our unanimous desire to bear witness hereby to his many good qualities; to his kind heart and cheery disposition, which made friends for him everywhere; to his fearless aggressiveness for what he considered right; to his ability, which won for him a high place in the engineering circles of our country; to his genius, which led him to research work in unknown fields, and resulted in developments which will be a benefit to the world. We sincerely mourn his loss as a friend, and deplore the loss the world has suffered, in being deprived of his services.

Be It Further Resolved, That our sincere sympathies, with copies of these resolutions, be extended to his bereaved family.

Pittsburgh, Pa. October 1, 1912.

N. W. Storer, J. D. Forrer,
C. B. Auel, M. B. Lambert,
G. M. Eaton, C. Renshaw,
Robert L. Wilson, S. M. Kintner,
Walter V. Turner, L. M. Aspinwall,
Committee.

NEW BOOKS

"Transmission Line Construction"—A. H. Lundquist. 295 pages, 180 illustrations. Published by the McGraw Hill Book Company. Price $3.00.

This book treats of the materials of line construction and methods of constructing transmission lines, but does not take up the problems of designing transmission lines. It is essentially a book of practical methods treating the subject from the standpoint of a construction man rather than of the office engineer. Considerable attention is given to various types of pole line construction and to detail cases. The final chapter is devoted to the organization and tools for erecting transmission lines.

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NEW BOOKS

"Wireless Telegraphy and Wireless Telephony"—Charles C. Ashley and Charles B. Hayward. 141 pages. Illustrated. Published by American School of Correspondence, Chicago, Ill. Price, $1.00.

This book is of the same general type and arrangement as previous text-books issued by this school. It gives the historical developments of wireless methods and explains in an elementary manner the various schemes of signaling which have been developed. No attempt is made to describe commercial forms of apparatus, but many diagrams of connections are included, with explanations describing the principles involved. To the non-technical stuednt this book should prove to be a good means of securing general information regarding wireless telephony and telegraphy.

"Elements of Drawing"—G. F. Blessing and L. A. Darling. 193 pages, 152 illustrations. Published by John Wiley & Sons, New York City. Price, $1.50.

This is an elementary text-book for beginners and is based on the drawing courses used at Sibley College, Cornell University. It is intended as a companion volume to the author's "Elements of Descriptive Geometry."

WANTED.

Young man with good technical training, preferably with some engineering experience, as Assistant Editor on a prominent Electrical Periodical. Initiative, originality and agreeable personality essential. Address, No. 556 Care The Electric Journal, Pittsburgh, Pa.

WANTED.

Two second-hand 75 kilowatt, 220 volt, 375-425 r.p.m. direct-current generators. The Loew Mfg. Company, Cleveland, Ohio.

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Technically educated young men for our dynamo and transformer testing departments. Good wages and opportunities for college graduates. Apply at Employment Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

FOR SALE.

Aylmer-Small's Electric Railroading $2.00
A. I. E. E. Catalogue of Wheeler Gift (2 vols.) 7.00
Anthony's Theory of Electrical Measurements ..... .50

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(E) W. B. Flanders. p. 214, Mar., '11.

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